
**Eastern South Dakota Soil and Water
Research Farm**

1992

**Annual Report to the
Board of Directors**

**USDA, ARS, Brookings SD
USDA, ARS, Morris MN
South Dakota State University**

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HISTORY OF THE EASTERN SOUTH DAKOTA SOIL AND WATER RESEARCH FARM

The Eastern South Dakota Soil and Water Research Farm, Inc. is a non-profit organization consisting of a Board of Directors elected from each of 15 Soil and Water Conservation Districts in eastern South Dakota. Brookings, Codington, Clark, Day, Deuel, Hamlin, Kingsbury, Lake, Lincoln, Marshall, McCook, Minnehaha, Minor, Moody, and Turner Soil and Water Conservation Districts are represented on the Board of Directors. The purpose of the corporation is to promote research of efficient farm production practices that conserve soil and water resources.

The corporation bought 100 acres of land in Lake County, South Dakota, near the community of Madison in 1959. This land was leased to the Agricultural Research Service, United States Department of Agriculture. The work performed at the Madison farm included evaluation of the erosion of different soil types; development of tillage practices to conserve soil and water; determination of efficient crop production methods; and modeling plant-insect interactions. Research was conducted by scientists from the North Central Soil and Water Conservation Laboratory, ARS, Morris, MN; the Northern Grain Insects Research Laboratory, ARS, Brookings, SD; and the South Dakota State Agricultural Experiment Station.

The Board of Directors decided to relocate the research farm closer to the research laboratories to improve program efficiency and facilitate productive cooperative research programs that would more effectively solve some of the problems that are associated with agriculture in eastern South Dakota. The Madison research farm was sold in 1987, and the Corporation bought another tract of land in Brookings County.

The Brookings research farm consists of 80 acres located approximately one mile north of the campus of South Dakota State University. The soils found on this farm are characteristic of those found in northeastern South Dakota and west central Minnesota and are similar to soils common to the northern corn belt.

RESEARCH PROSPECTUS

Safety of ground water from chemical contamination and the long-term economic viability and environmental compatibility of agricultural production practices is the foremost concerns of the public, farmers, and the scientific community. The widespread use of fertilizers and pesticides for agricultural production poses several significant and interdependent problems. Agricultural chemical contamination of ground water supplies has the potential for catastrophic impact upon human health, wildlife, and the environment. The high energy and economic costs associated with the production and use of fertilizers and pesticides may cause conventional crop production practices which rely on high levels of chemical inputs to become economically unfeasible in the near future. The deleterious environmental and economic consequences of conventional high-input farming practices are threatening the future of the family farm and rural communities. This sociological and economic upheaval will undoubtedly worsen if we continue along our current course.

The problems outlined above are complex, and therefore have no simple solution. No single scientific discipline can adequately address these problems in a manner that will achieve effective solutions. Rather, scientists representing many disciplines will need to join forces and focus simultaneously on these problems with the goal of finding acceptable solutions. This research farm provides the impetus and the opportunity for the scientific personnel from South Dakota State University and the Agricultural Research Service to address the complex problems outlined above. A research program that integrates many scientific disciplines from the various institutions is truly a meaningful way to focus on the complex ground water quality and sustainable agriculture.

1992 Planning Committee Actions

A meeting of the scientists who perform research at the Brookings Research Farm was held on September 15, 1992 at the Northern Grain Insects Research Laboratory. The purpose of the meeting was to coordinate research activities at the research farm and to discuss input levels to the crop rotation input level experiments.

The low input treatments applied to the continuous corn and corn/soybean rotation plots were discussed. It was suggested that additional chemicals needed to be applied to these plots in order to reduce weed impact and improve crop growth. Various management strategies, such as increased cultivation and manure applications, were discussed as a way to improve the condition of these low input plots. It was decided that more tillage was not a practical solution. Manure application, while improving organic matter and fertility, would lead to other problems. These problems include variability in the composition and nitrogen level between loads, creation of habitat for insect pests, problems with uniform application, and bringing in new weed seeds to the plots. Although the need to include manure on the low input plots is apparent, it was decided to keep the present input levels for all of the plots.

The need for additional technical support help during critical periods during the growing season was mentioned. Because of a lack of funds, it was decided that hiring additional workers for the summer was not possible. It was decided that a list of projects, such as picking rock and pulling weeds, would be circulated among the researchers that use the crop rotation plots, and that the various groups would contribute time to complete these projects at their discretion.

The utility of the Annual Report to the Board of Directors was discussed, and it was decided to continue the practice. Dave Woodson volunteered to organize the next report.

People in Attendance

Sharon Clay
Kevin Kephart
Tom Schumacher
Jan Jackson
Dave Woodson
Mike Lindstrom
Walt Riedell
Pete Stegenga
Mike Ellsbury
Max Pravacek

1992 Crop Report

Max Pravacek

USDA, ARS, Northern Grain Insects Research Laboratory

The 1992 Input Plot growing season saw: Sharon Clay (SDSU) and Frank Forcella (USDA, Morris) monitor weed populations, Bob Kieckhefer (USDA, Brookings) monitor insect populations in wheat, alfalfa, and grass plots, Dave Woodson (USDA, Brookings) monitor adult corn rootworm emergence, Kevin Kephart (SDSU) monitor grass plots, Mike Ellsbury (USDA, Brookings) monitor ground beetle populations, Jan Jackson (USDA, Brookings) infested nematodes in corn plots for corn rootworm control, and Walter Riedell (USDA, Brookings) took soil monoliths from the corn plots.

The plots were planted at normal planting time and received similar treatments as last year's plots. Additional nitrogen was applied to high input plots to achieve 125-130 bu. corn yield and to integrated plots to achieve 80-85 bu. corn yield. Low input plots received no supplemental nitrogen.

An analysis of yield data was done using GLM SAS program for analysis of unbalanced data ($P < 0.05$).

Alfalfa yields for high, integrated, and low input plots were not statistically different.

Wheat yields were greatest for high input and least for low input.

As can be expected, mean soybean yields for the three input levels, high, integrated, and low, show greatest yields occurred with high input and least for low input. Mean soybean yields for the three rotations, Corn/Soybean, Corn/Soybean on ridges and Four Year

(Corn/Soybean/Wheat/Alfalfa rotation) show greatest yield occurred in the Four Year rotation. Corn/Soybean and Corn/Soybean on ridges were almost identical.

For the corn crop, mean corn yields for the three input levels show best yields for high input and worst for low input. Mean corn yields for Continuous Corn, Corn/Soybean, Corn/Soybean on ridges, and Four Year rotations show highest yield for the Four Year rotation. Corn/Soybean and Corn/Soybean on ridges less than the Four Year rotation but similar to each other and the Continuous Corn rotation the lowest yield.

The following tables show yield for all crops and statistical differences in inputs and rotations.

1992 Mean Corn Yield (Bu/Acre)

Input	Continuous Corn	Corn/Soybean	Corn/Soybean on Ridge	Four Year	Mean Input Yield
High	93.5 a,x	103.8 a,x	101.7 a,x	97.5 a,x	99.1
Int.	56.0 b,x	82.2 b,y,z	67.3 b,x,y	87.7 a,b,y,z	73.3
Low	10.2 c,x	4.4 c,x	41.5 c,y	80.0 b,z	36.5
Rotation Mean Yield	53.3	66.8	70.2	88.4	

1992 Mean Soybean Yield (Bu/Acre)				
Input	Rotation			Mean Input Yield
	Soybean/Corn	Soybean/Corn on Ridge	Four Year	
High	30.4 a, x	30.0 a, x	30.6 a, x	30.3
Int.	27.5 a, x	26.0 a, x	29.0 a, x	27.5
Low	13.0 b, x	14.4 c, x	19.9 b, y	15.8
Rotation Mean Yield	23.6	23.5	26.5	

Input	<u>1992 Mean Wheat Yield</u>	<u>1992 Mean Alfalfa Yield</u>
	Bu/Acre	Ton/Acre
	Four Year Rotation	Four Year Rotation
High	31.5 a	3.6 a
Int.	26.0 b	3.2 a
Low	13.0 c	3.5 a

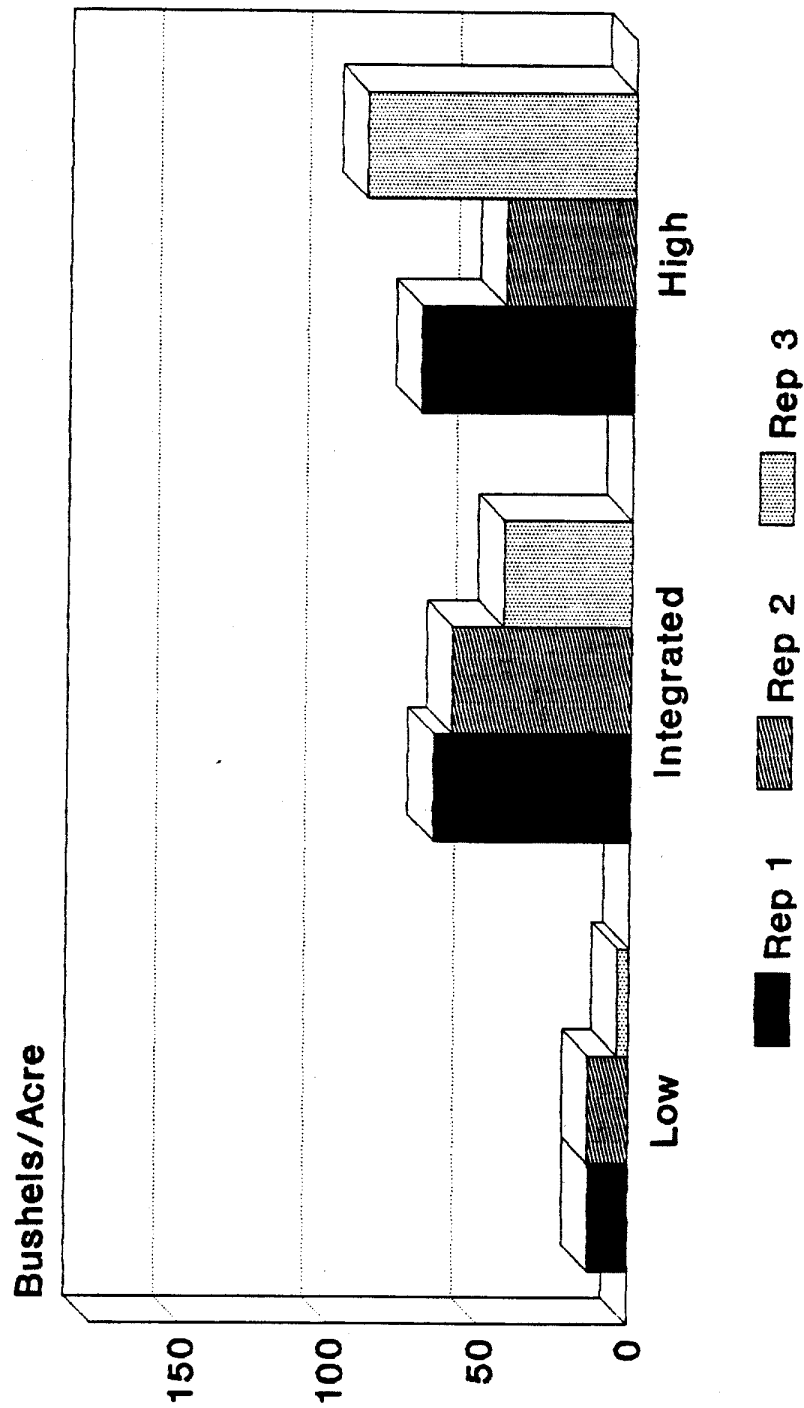
Means in columns followed by a, b, or c are significantly different at $P = 0.05$.

Means in rows followed by x, y, or z are significantly different at $P = 0.05$.

Four Year rotation is Corn/Soybean/Wheat/Alfalfa cropping system.

1992 Corn Yield

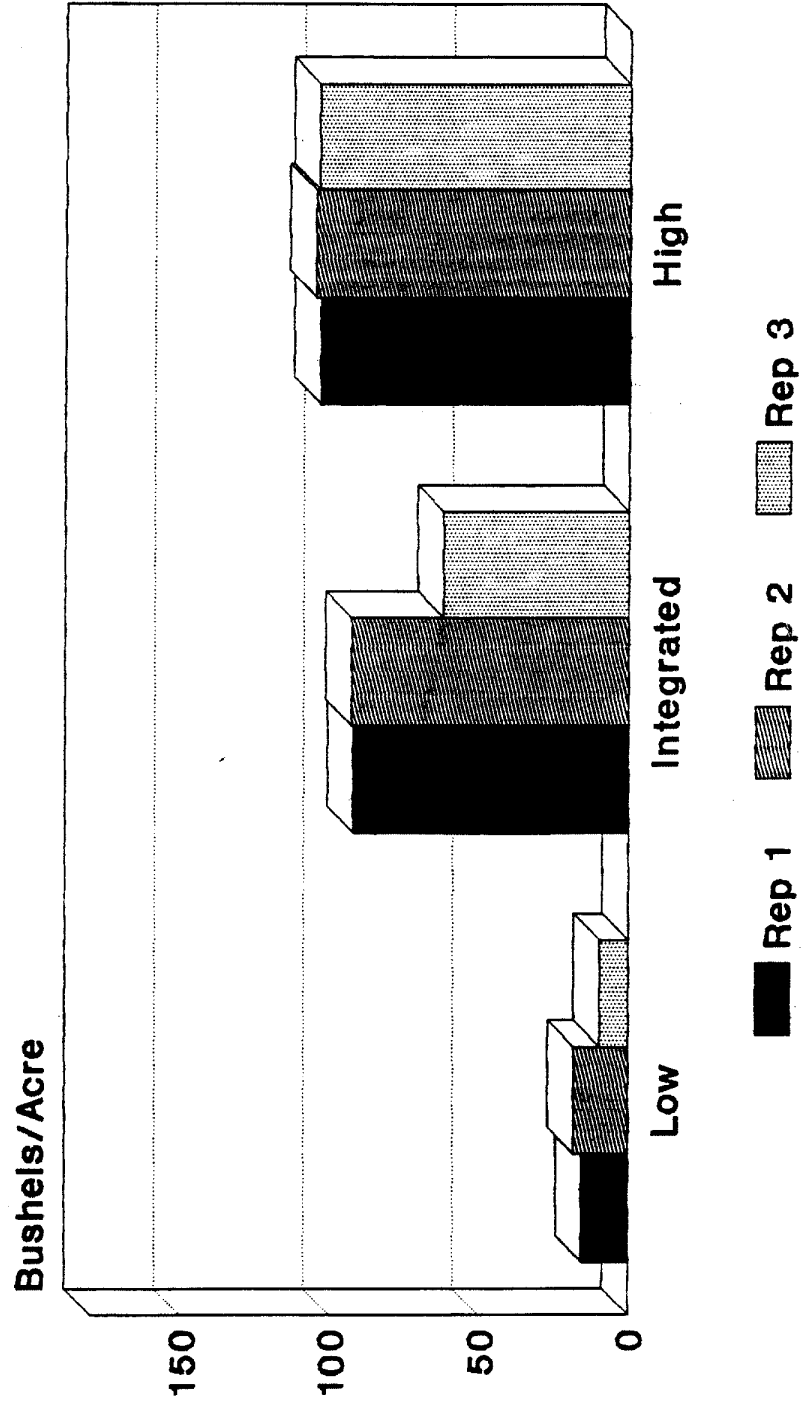
Continuous Corn



USDA Research Farm

1992 Corn Yield

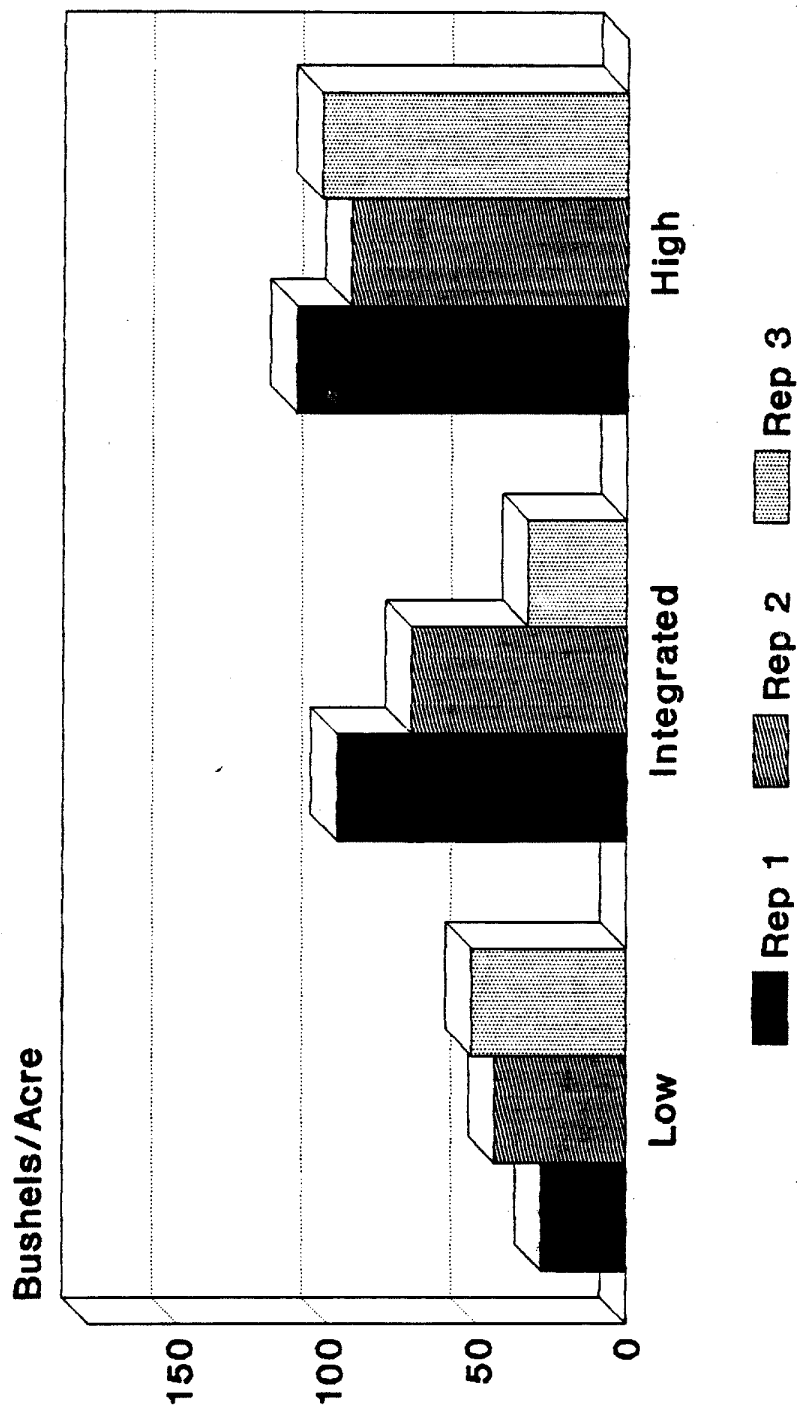
Corn Soybean Rotation



USDA Research Farm

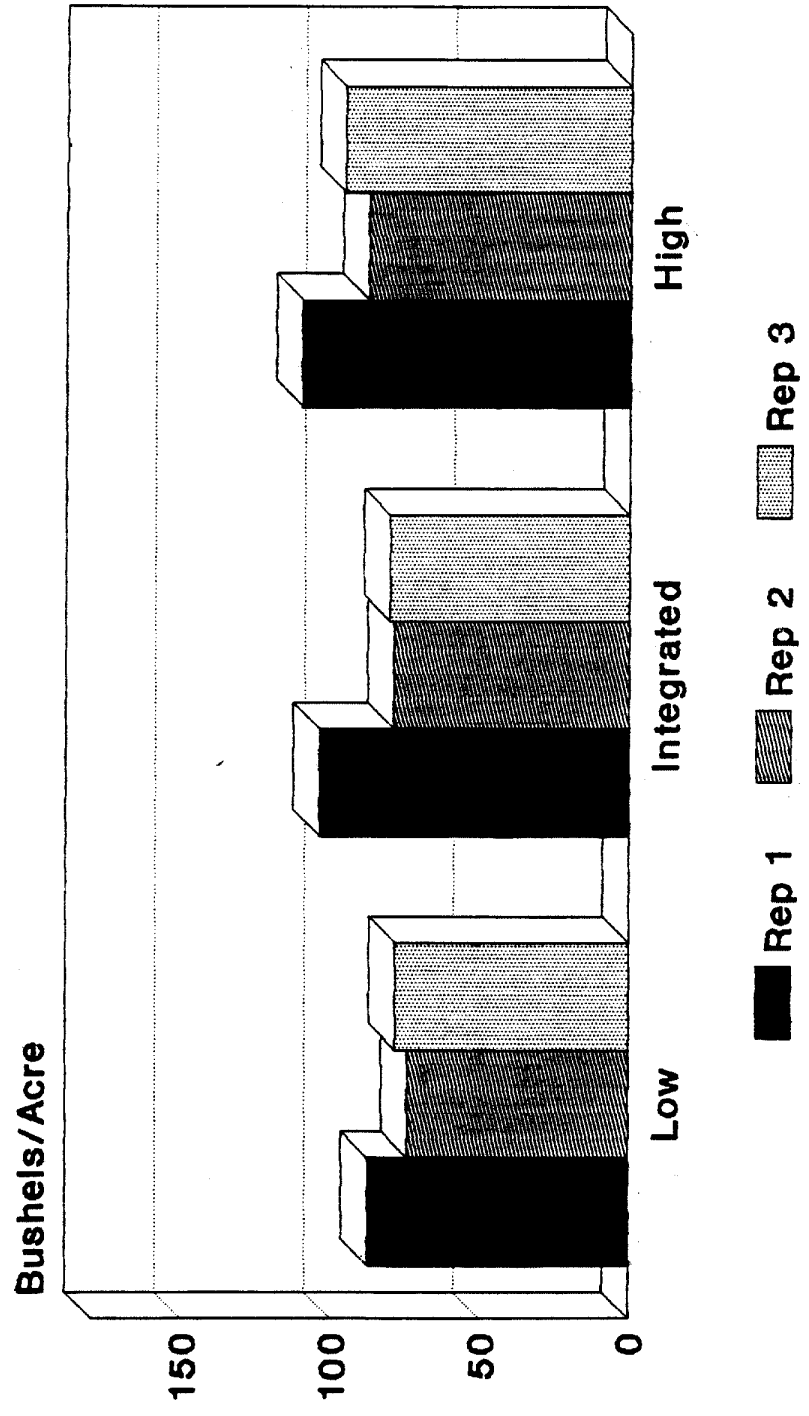
1992 Corn Yield

Corn Soybean Rotation on Ridges



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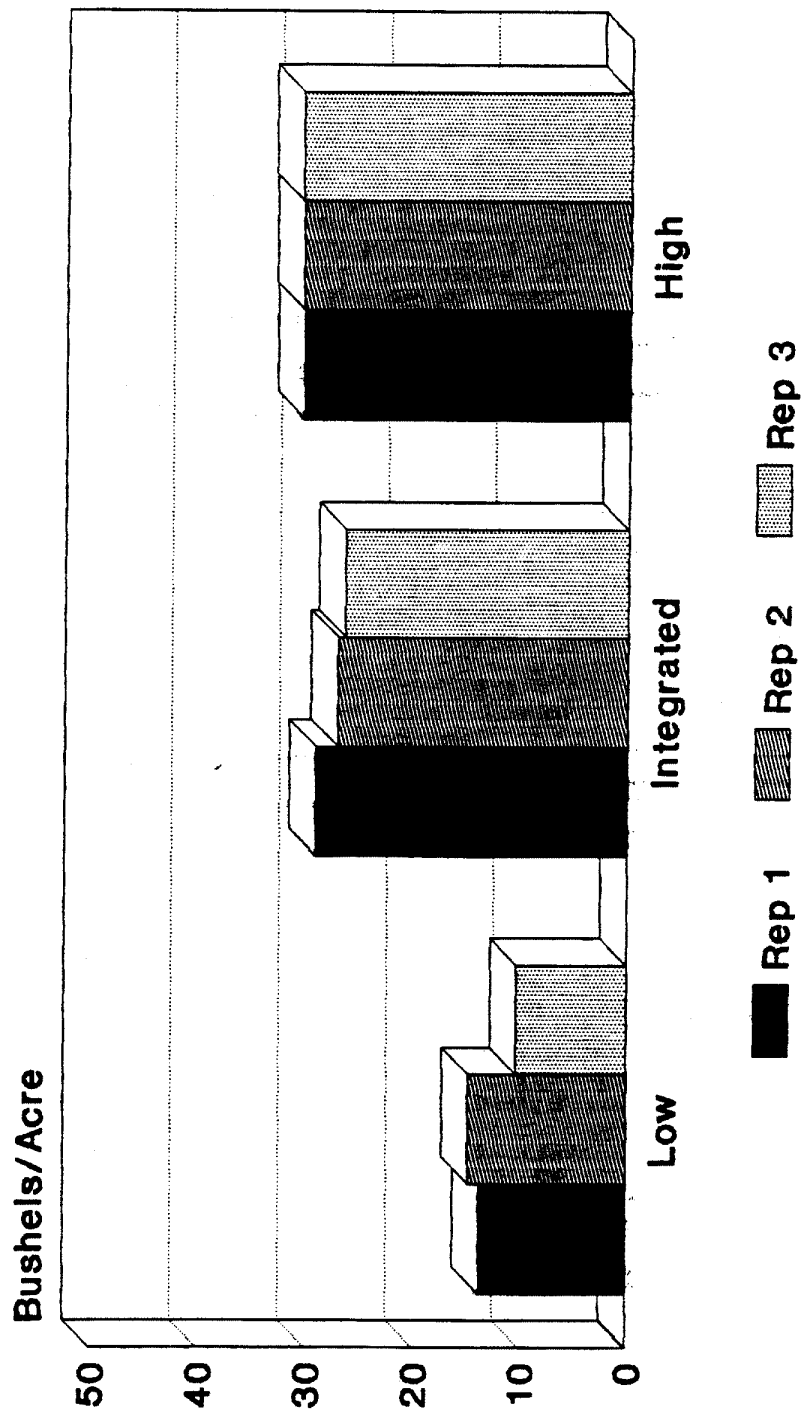
1992 Corn Yield 4 Year Rotation



USDA Research Farm

1992 Soybean Yield

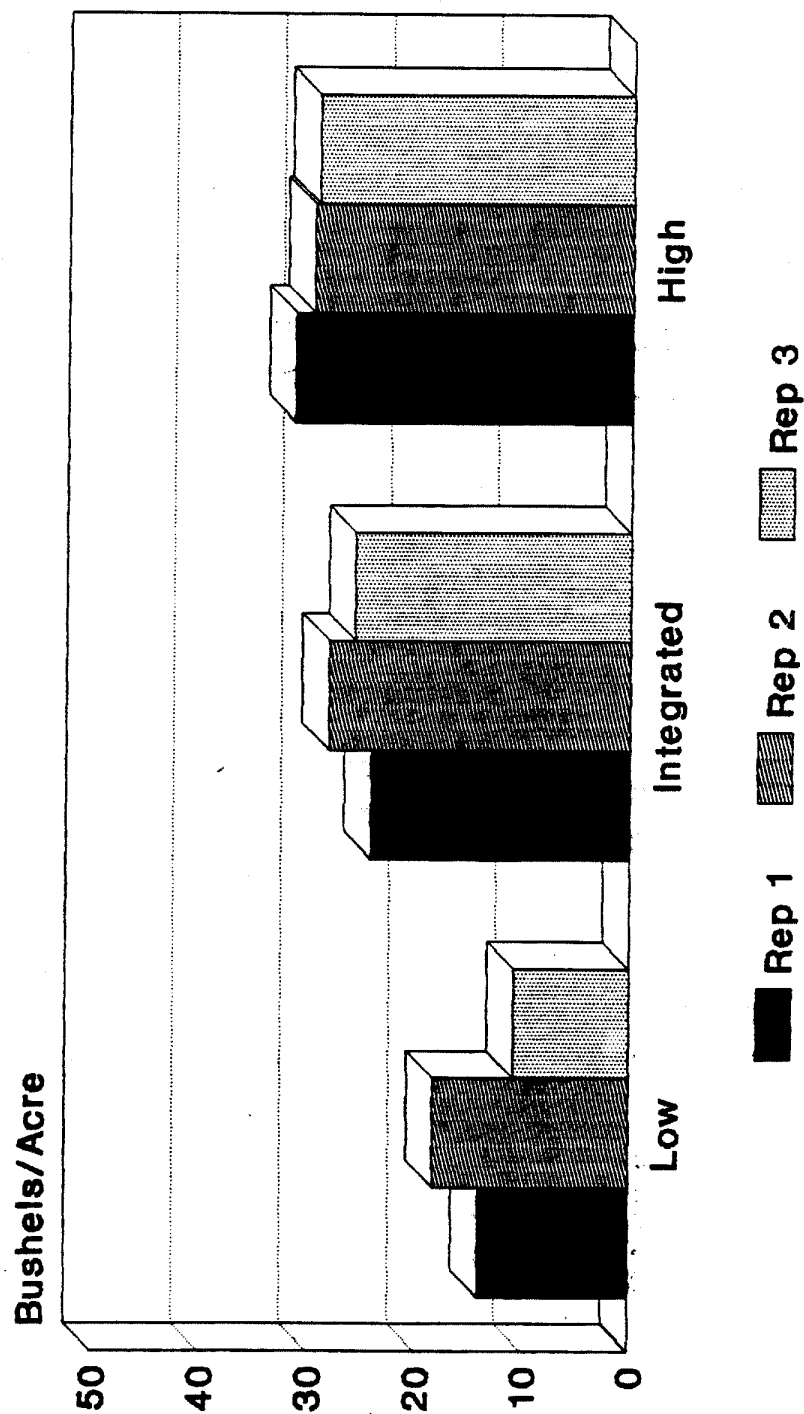
Corn Soybean Rotation



USDA Research Farm

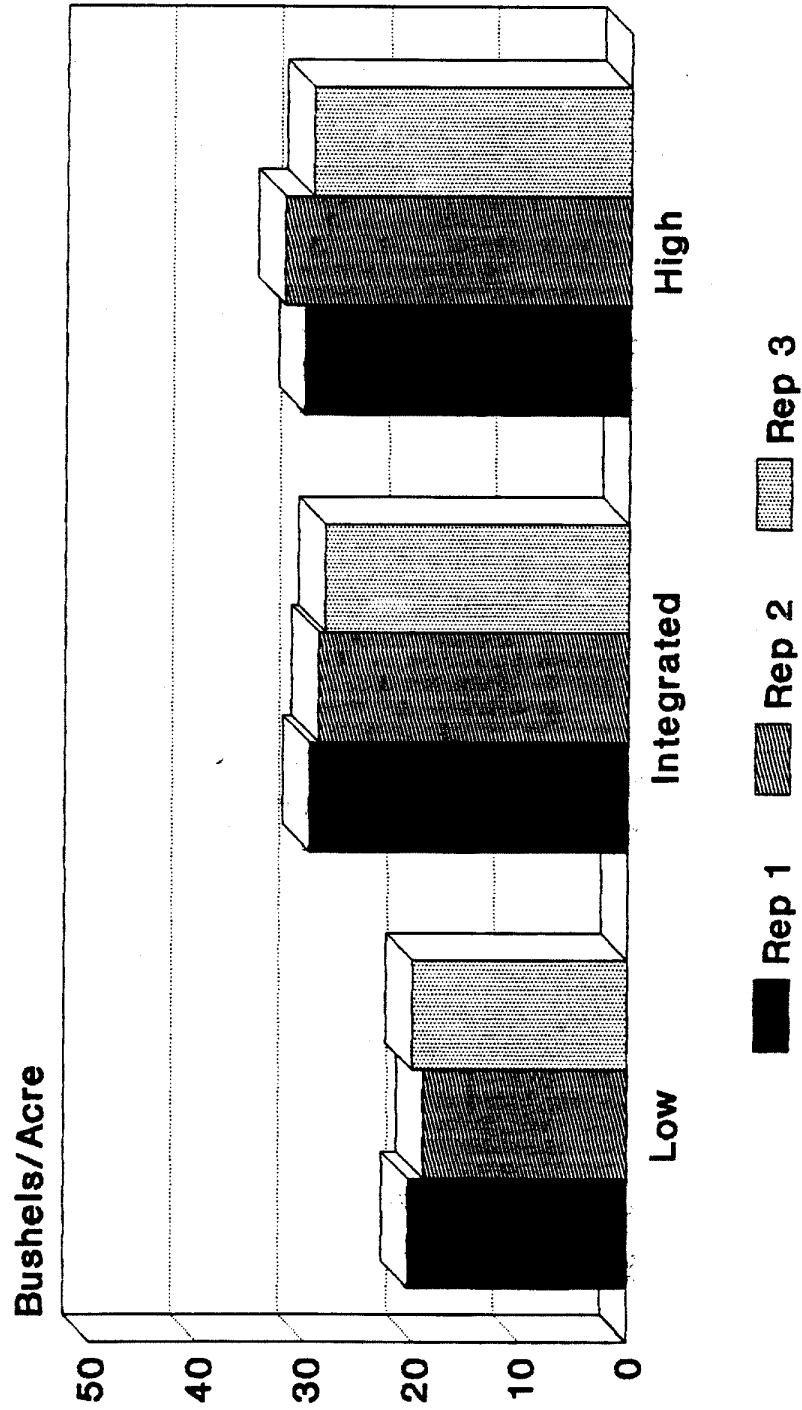
1992 Soybean Yield

Corn Soybean Rotation on Ridges



USDA Research Farm

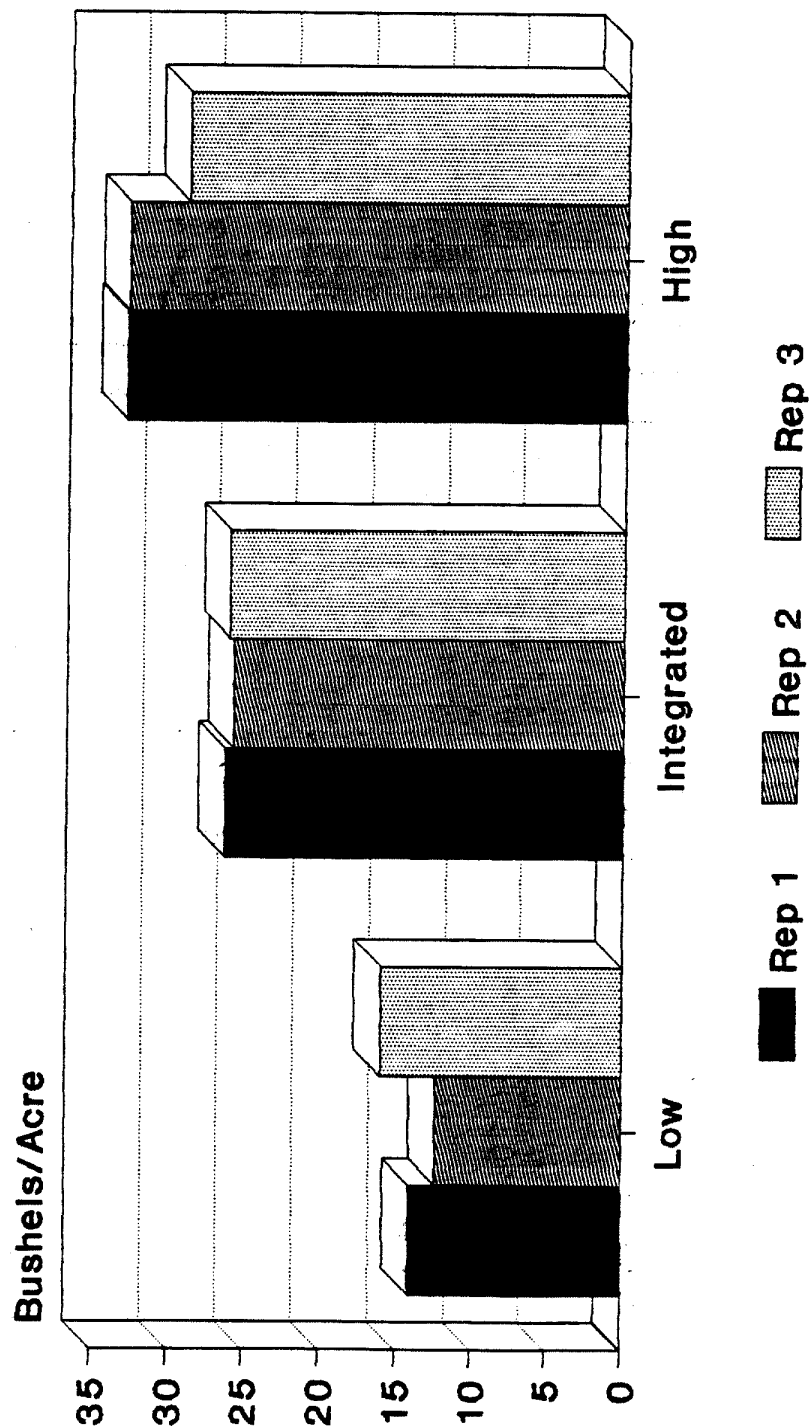
1992 Soybean Yield 4 Year Rotation



USDA Research Farm

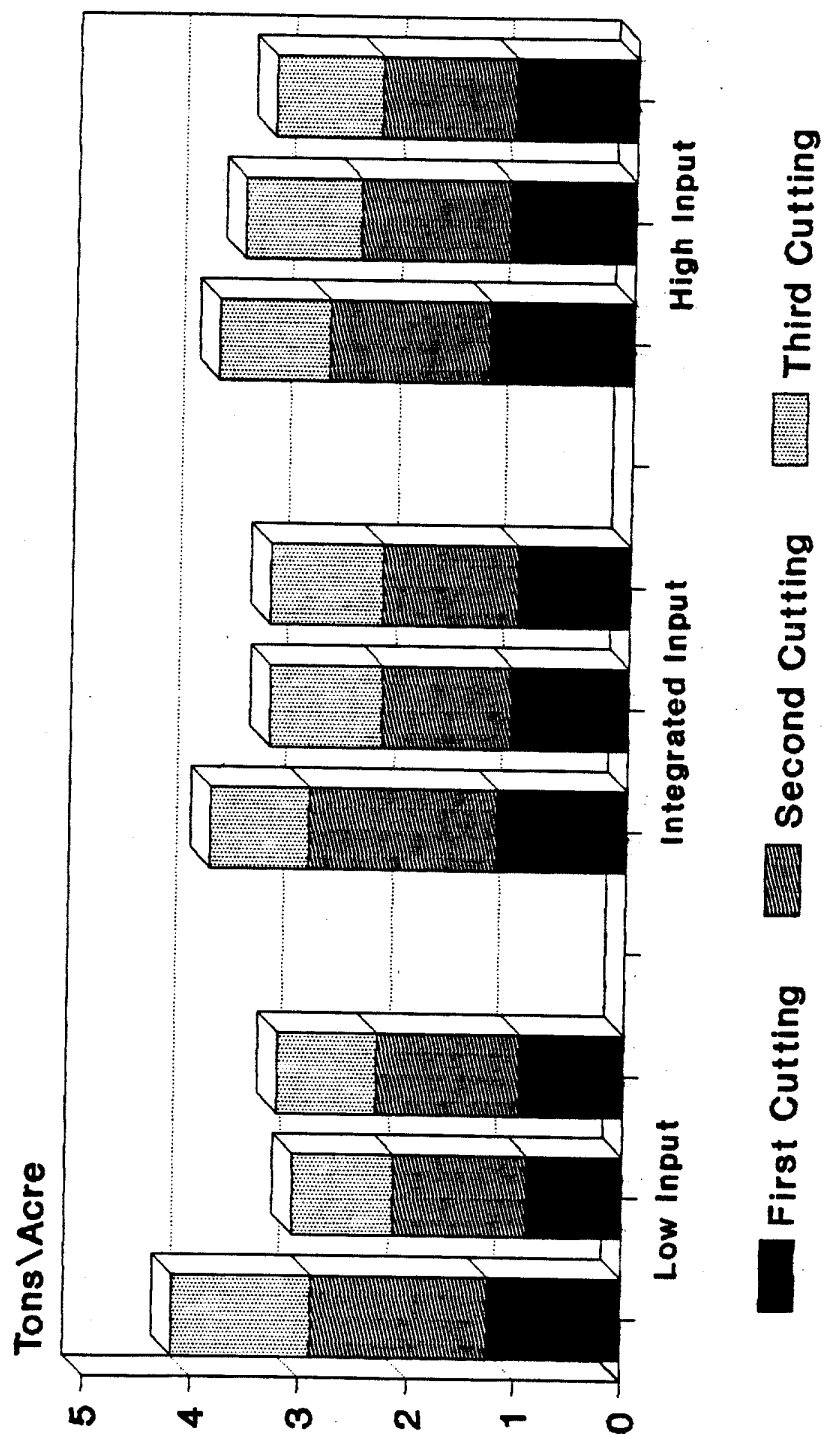
1992 Wheat Yield

4 Year Rotation



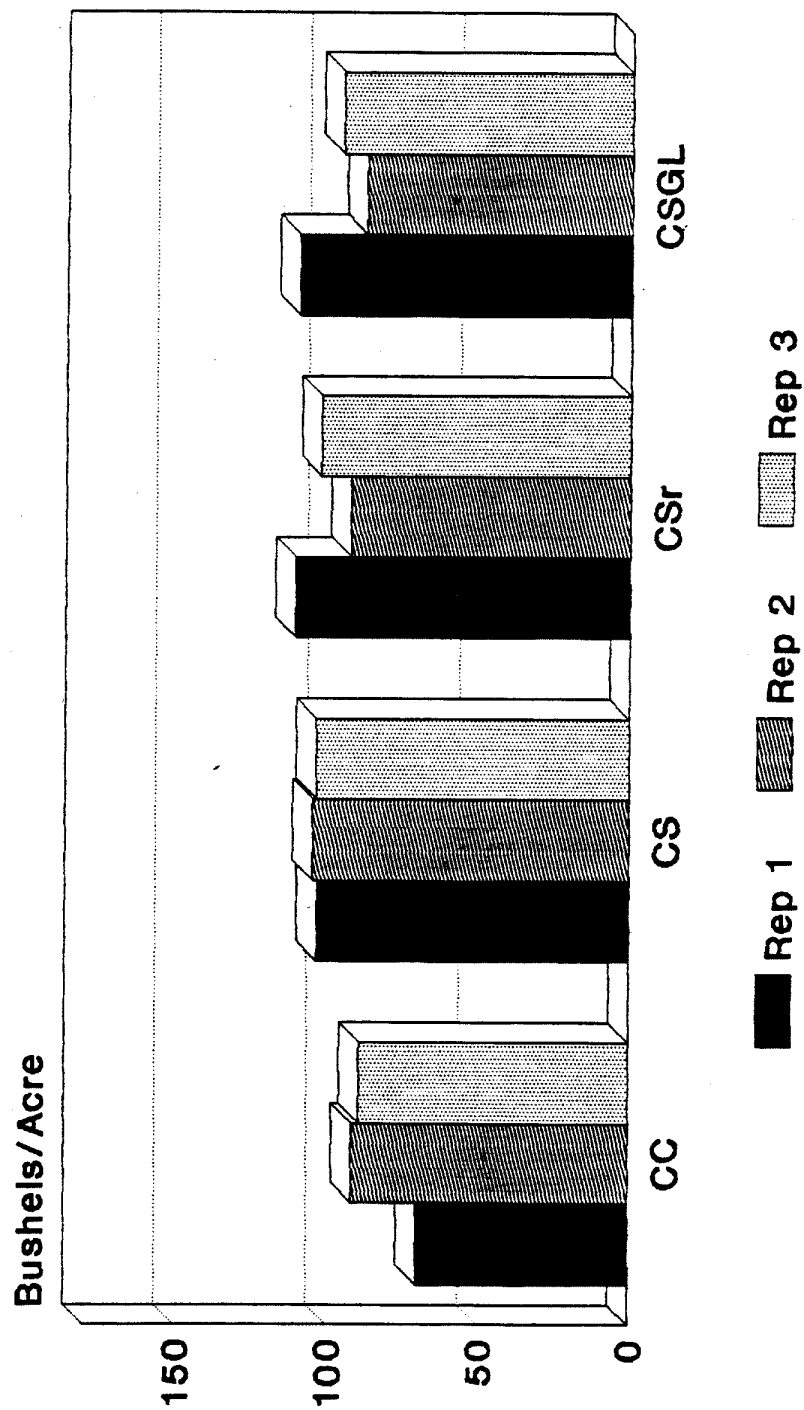
USDA Research Farm

1992 Legume Yield 4 Year Rotation



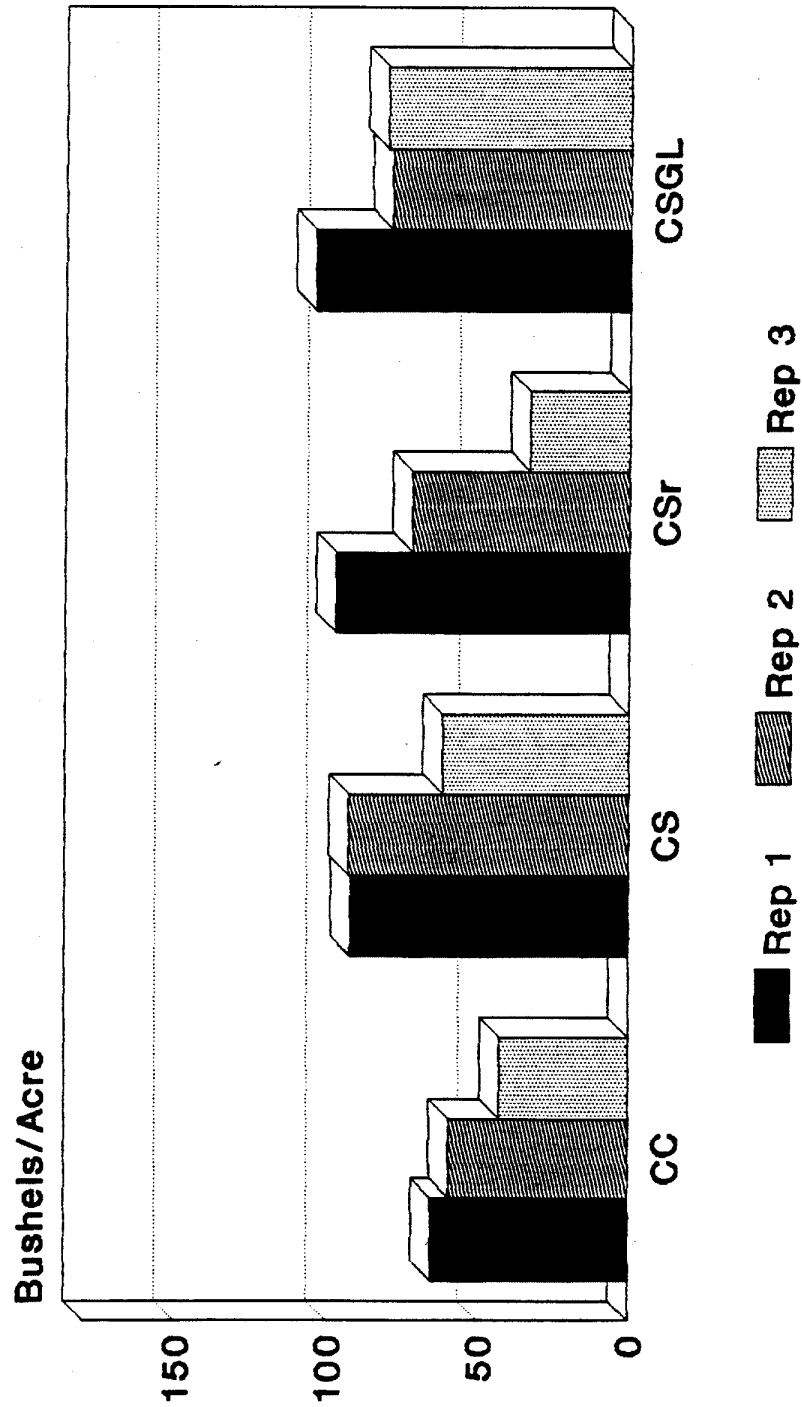
1992 Corn Yield

High Input



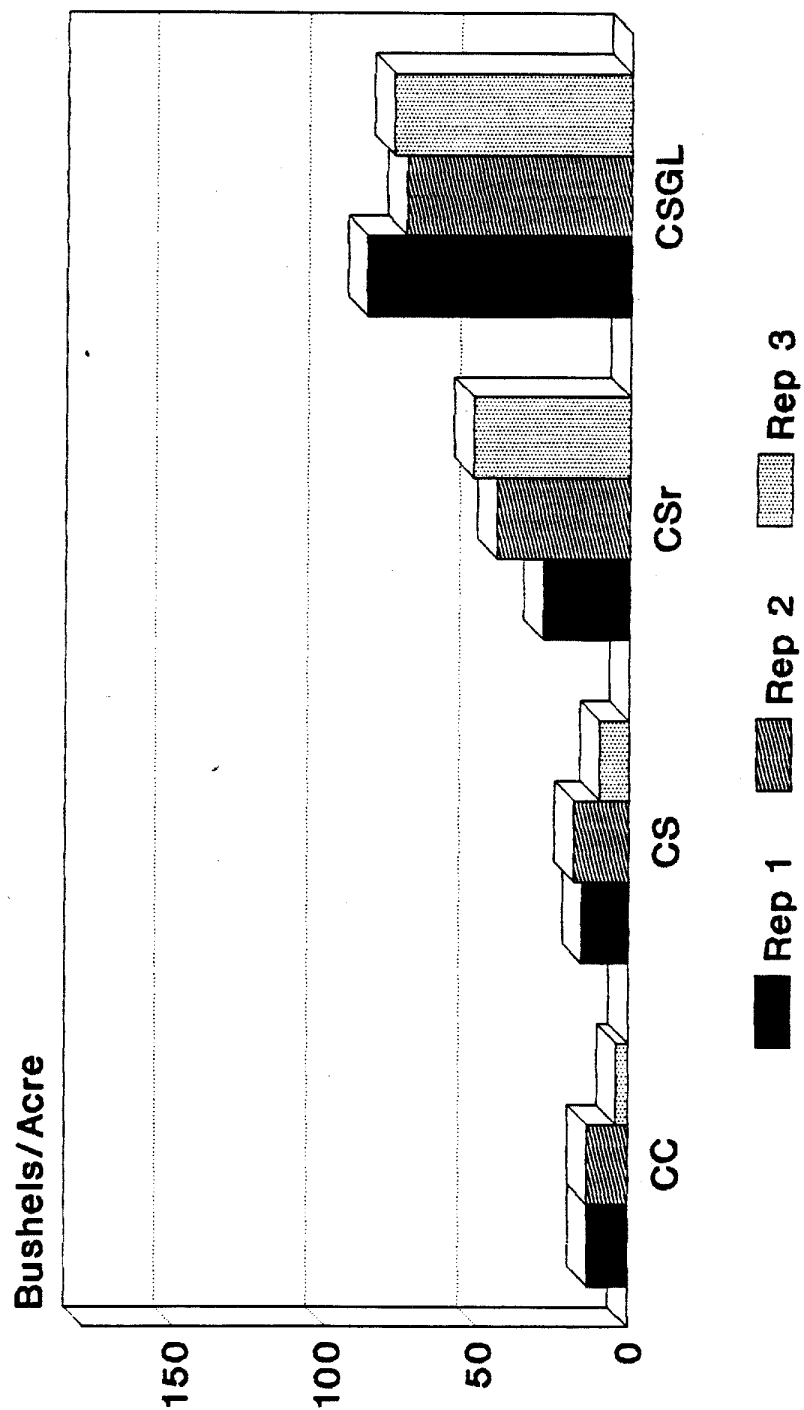
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1992 Corn Yield Integrated Input



1992 Corn Yield

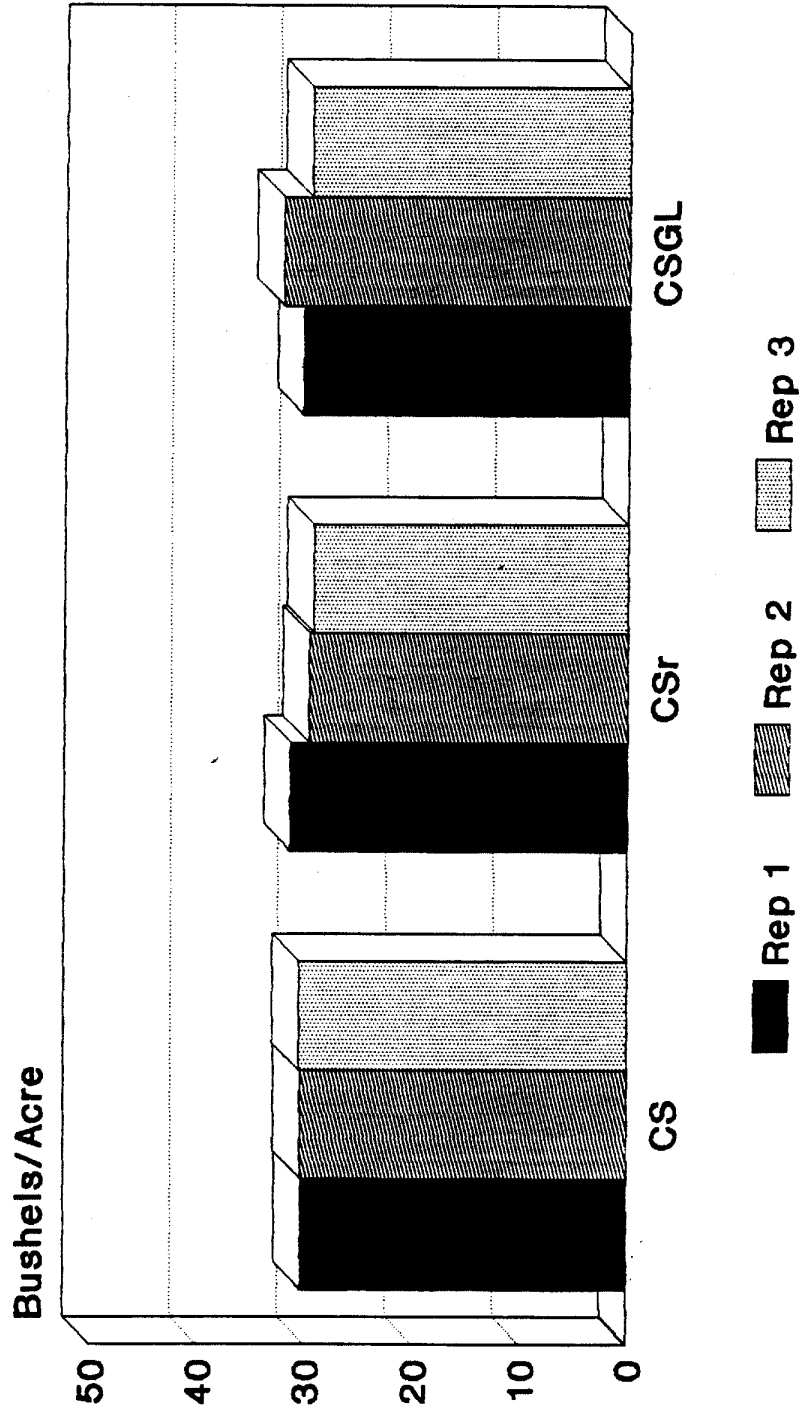
Low Input



USDA Research Farm

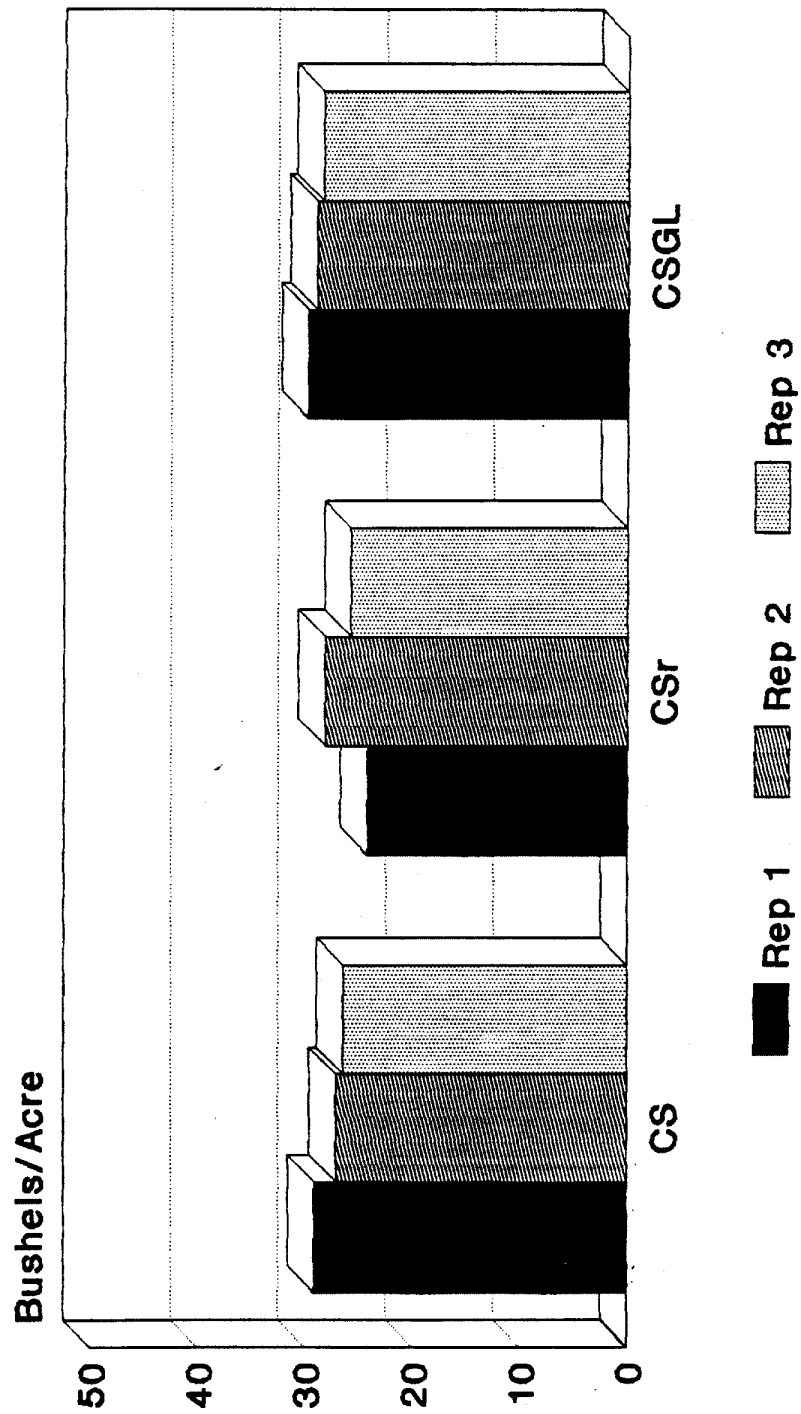
1992 Soybean Yield

High Input



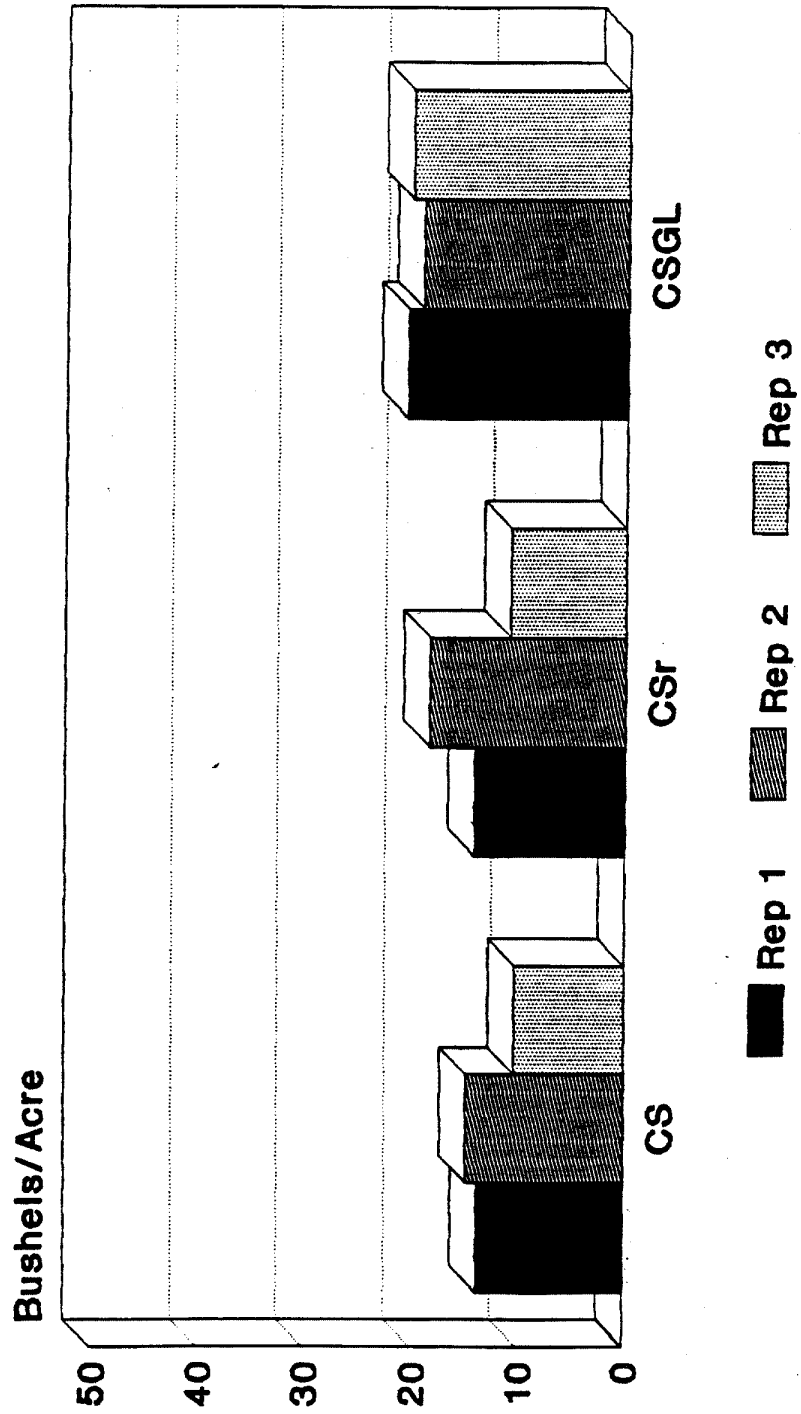
1992 Soybean Yield

Integrated Input



USDA Research Farm

1992 Soybean Yield Low Input



INFLUENCE OF MANAGEMENT TREATMENTS IN VARIOUS CROPS ON THE ABUNDANCE AND DIVERSITY OF INSECT POPULATIONS

**D. A. Beck and R. W. Kieckhefer
USDA, ARS, Northern Grain Insects Research Lab**

Materials and Methods

Our research objective at the Eastern South Dakota Soil and Water Research Farm (ESDSWRF) is to determine the influence of management treatments (minimum input, integrated, and conventional) in wheat and alfalfa on the abundance and diversity of insect populations in the aerial vegetation of these crops. Emphasis is on populations of the major economic insects of the crops. In this our third consecutive year of study on the ESDSWRF research plots sampling continued to be carried out in wheat and alfalfa as it had been done the previous year. However, sampling was not done in the grass plots because they were turned under and are being reestablished owing to a poor take of warm season grass species and the encroachment of weedy annuals.

Insect populations were sampled by collecting two 30-sweep net subsamples from each of the nine 30.5 m x 30.5 m plots (three treatments - low, integrated and high input - each being replicated three times). A total of 18 30-sweep net subsamples were obtained from a crop type on a given sampling date. Insects in the samples were anesthetized using chloroform, transferred to containers, and frozen for later processing. When processing the samples they were enumerated by taxon groups as outlined in Figure 1 (dry weight biomass determinations were not made as had been done in 1990 and 1991). The number of taxa

considered in 1992 was less than in 1991 but sampling was conducted on more dates than in the previous year. The following taxa groupings were considered in both crop types: common damsel bug (Nabis americanoferus), common green lacewing (Chrysoperla plorabunda), aphids (Aphididae), and lady beetles (Coccinellidae). Except for aphids (adults and nymphs combined) the developmental stage was segregated for these taxa. No attempt was made to differentiate between the various aphid species involved. The species of lady beetles were distinguished but for purposes of numerical data summary they were lumped together. The wheat stem maggot (Meromyza americana) (adults) was only enumerated in the wheat. The potato leafhopper (Empoasca fabae) (adult and nymph combined) and alfalfa weevil (Hypera postica) (adult only) were only enumerated in alfalfa.

A "presence/absence method" was used in the field to obtain the data on aphids in wheat. Fifteen tillers (5 groups of 3 consecutive tillers) were examined per plot, and the data expressed as the percent of tillers infested with aphids. In alfalfa aphid abundance was ascertained from the sweep net collection samples, however, a numerical rating scale was utilized instead of making an outright count as was done with all other taxa groups.

On 17-18 July 1992 a tally of wheat stem maggot "damage" (i.e. white heads) was done in the wheat. A count of damaged/white heads was made using a 0.09 m² quadrat (50 readings per plot); a count of the total number of wheat heads per quadrat (10 readings) was also made and the data expressed as the per cent of heads damaged.

Information on various kinds of vegetative parameters were collected and records of meteorological conditions were taken each time a crop was sampled for insects, but rather

than re-elaborate here, the reader is referred to the 1991 ESDSWRF Annual Report for specific details on how this was done.

The 1992 chronology/phenology of sampling in each of the crop types was as follows:

Wheat - 2 June (late tillering), 10 June (late boot),
 22 June (anthesis), 8 July (soft dough), and,
 20 July (soft dough) = total of 5 sampling dates
 [wheat planted 7 April / harvested 10 August]

Alfalfa - 28 May (early bud), 2 June (late bud), 22 June
 (pre-bud), 8 July (< 10 % flowering), 20 July
 (> 50 % flw.), and, 4 September (bud) = total of 6
 sampling dates

1st cutting - 3 June, 2nd cutting - 20 July,
 3rd cutting - 14 September]

Results and Discussion

Six species of lady beetle adults and four species of larvae were encountered in the wheat plots and nine and four species respectively were found in alfalfa (Figure 2). Alfalfa typically supports a more diversified population of lady beetles than do small grain cereal crops. In wheat pink and black (Coleomegilla maculata) and convergens (Hippodamia convergens) accounted for over three-fourths of the total number of lady beetles adults. Parenthesis (H. parenthesis) made up nine percent with the remaining three species comprising 14 percent of the total. Pink and black larvae (50 percent composition) also

predominated in the wheat. Together parenthesis and European seven-spotted (Coccinella septempunctata) comprised 46 percent with 13-spotted (H. tredecimpunctata tibialis) making up the remaining four percent. No evidence of convergens lady beetle reproduction was observed in the wheat even though they made up one-third of the adults encountered. In alfalfa convergens adults made up 59 percent followed by parenthesis and pink and black with 19 and 11 percent respectively. The other six species of adults accounted for the remaining 11 percent composition. Parenthesis attributed over three-fourths of the larvae with 13-spotted comprising 11 percent and together convergens and pink and black making up the remaining 12 percent.

As a preface to the following discussion it is noted that only treatment means are presented for information purposes. Tests of statistical analysis have yet to be done on the numerical abundance data, so only general statements of trends can be made and no significance is implied. Also, analysis/summaries of plant and meteorological data are not being done at this time.

Generally the numerical abundance of individuals in the insect taxa groups we enumerated in 1992 was reduced from that found in the previous field season. The percent of wheat tillers infested with aphids was greater in the integrated and low input plots (Table 1). This is in contrast to the 1990-91 field seasons in which the incidence of aphid infestation was greatest on the high input plots. There was essentially no difference in the percentage of heads damaged by wheat stem maggots; also, no definite trends in the occurrence of wheat stem maggot adults in the sweep net collections was evident across the three input treatments. Both the average number of taxa groups occurring and the total

number of individuals found for all taxa per sub-sample trended towards the integrated and high input plots. Lady beetles are beneficial insects in that they are important predators of the aphid pests present in crops. Both lady beetle adults and larvae were present in greater abundance on the high input plots with integrated being next in line (this is somewhat the same tendency exhibited by the previous two years data). Since the percent of aphid infestation was greatest in integrated plots followed by low input plots, one could expect the occurrence of lady beetles to also be greater on these plots respectively, but this was not the case. Other "aphidophagous" (predators of aphids) insects we considered were damsel bug adults and nymphs and lacewing larvae (adult lacewings are plant feeders). Both damsel bug adults and lacewing larvae were greatest on the high input plots and lowest on the low input plots. Very little difference between treatments was exhibited by the occurrence of damsel bug nymphs. Lacewing adults were highest on integrated plots and lowest on the low input plots.

The numerical abundance of aphids in alfalfa was greatest in the high input plots and lowest on integrated (Table 2). This is opposite the relationship found in wheat in which the incidence of aphids was greatest on integrated and lowest on high input plots. Another reverse trend of that found in wheat was exhibited in alfalfa with both the number of taxa and total numbers for all taxa being greatest on the low input treatment. For the aphidophagous insect taxa the results are somewhat ambiguous. Occurrence of damsel bug adults and nymphs was greatest on integrated but for lady beetle adults and larvae was lowest on the integrated plots, however, the differences between treatments were not relatively that great. No apparent difference in lacewing larvae (as well as the non-aphidophagous adults)

across treatments was present. The potato leafhopper and alfalfa weevil are insects of economic importance that when present at very high levels have the potential to cause great damage. In alfalfa the occurrence of both of these species was greatest on the low input treatment plots.

Figure 1. Comprehensive listing of insect taxa enumerated from sweep net sample collections in wheat and alfalfa, ESDSWRF, 1992.

Taxon	Development Stage	Crop Type	
		Wheat	Alfalfa
(PHYLUM ARTHROPODA / CLASS HEXAPODA):			
<u>Order HEMIPTERA</u>			
Family Nabidae - common damsel bug (<u>Nabis ameriicoferus</u>)	ad / ny ¹	X	X
<u>Order HOMOPTERA</u>			
Family Aphididae - aphids or plantlice	ad + ny	X	X
Family Cicadellidae - potato leafhopper (<u>Empoasca fabae</u>)	ad + ny		X
<u>Order NEUROPTERA</u>			
Family Chrysopidae - common green lacewing (<u>Chrysoperla plorabunda</u>)	ad / la ¹	X	X
<u>Order COLEOPTERA</u>			
Family Coccinellidae - lady beetles ²	ad / la ¹	X	X
Family Curculionidae - alfalfa weevil (<u>Hypera postica</u>)	ad		X
<u>Order DIPTERA</u>			
Family Chloropidae - wheat stem maggot (<u>Meromyza americana</u>)	ad	X	

¹Differentiate between developmental stages: ad = adult; ny = nymph; la = larvae

²Distinguish among the various lady beetle species

Figure 2. Species of lady beetles (COLEOPTERA: Coccinellidae) encountered in 1992 sampling of ESDSWRF research plots.

	PERCENT COMPOSITION			
	<u>Wheat</u>		<u>Alfalfa</u>	
	<u>adult</u>	<u>larvae</u>	<u>adult</u>	<u>larvae</u>
<u>Hippodamia convergens</u> - "convergens"	33	-	59	6
<u>H. tredecimpunctata tibialis</u> - "13-spotted"	5	4	1	11
<u>H. parenthesis</u> - "parenthesis"	9	23	19	78
<u>Coccinella septempunctata</u> - "European sevenspotted"	4	23	5	-
<u>C. transversoguttata richardsoni</u> - "transverse"	-	-	tr. ¹	-
<u>Coleomegilla maculata</u> - "pink & black"	44	50	11	6
<u>Cyclineda munda</u>	5	-	3	-
<u>Brachiacantha ursina</u>	-	-	1	-
<u>Hyperaspis undulata</u>	-	-	tr.	-
	100%	100%	100%	100%

¹tr. = < 1%

Table 1. Summary of data from sweep net sample collections in ESDSWRF wheat plots, 1992.

		INPUT LEVEL		
		<u>Low</u>	<u>Integrated</u>	<u>High</u>
Aphids (% of tillers infested)		10.2	13.3	9.8
Wheat Stem Maggot (% of heads damaged)		1.0	0.9	0.9
		<hr/>		
# of taxa	(of 7 taxa groups possible, does not include aphids)	1.4	2.1	2.0
total numbers - all taxa		2.4	4.6	5.1
# Damsel bugs - adult		0.9	1.0	1.6
	- nymph	tr. ¹	0.1	0.0
# Lacewings - adult		0.1	0.4	0.2
	- larvae	tr.	0.3	0.5
# Lady beetles - adult (6 species)		0.7	1.6	2.0
	- larvae (4 species)	0.1	0.2	0.3
Wheat stem maggot - adult		0.6	1.0	0.6

¹tr. < 0.1

Note: Except for the aphid and wheat stem maggot (% of heads damaged) data, these figures represent the mean value for a subsample consisting of 30 sweeps (two 30-sweep net subsamples per plot). Averaged over all three replicated treatment plot, both subsamples, and 5 sampling dates.

Table 2. Summary of data from sweep net sample collections in ESDSWRF alfalfa plots, 1992.

		INPUT LEVEL		
		<u>Low</u>	<u>Integrated</u>	<u>High</u>
# Aphids		62.4	60.7	65.0
# of taxa	(of 8 taxa groups possible, does not include aphids)	4.2	3.8	3.8
total numbers - all taxa (does not include aphids)		40.5	32.5	34.1
# Damselfly bugs - adult		5.1	5.2	4.8
- nymph		0.9	1.1	0.6
# Potato leafhopper - adults & nymphs		29.5	22.3	24.6
# Lacewings - adult		0.3	0.4	0.3
- larvae		0.4	0.3	0.3
# Lady beetles - adult (9 species)		2.2	1.9	2.4
- larvae (4 species)		0.3	0.1	0.2
# Alfalfa weevil - adult		1.8	1.3	0.8

NOTE: These figures represent the mean value for a subsample consisting of 30 sweeps (two 30-sweep net subsamples per plot). Averaged over all three replicated treatment plots, both subsamples, and 6 sampling dates.

Impact of Crop Rotation and the Capability of a Chlorophyll Meter in Determining Corn Nitrogen Concentration

**K. Brix-Davis, D.E. Clay, S.A. Clay, and T.E. Schumacher
South Dakota State University**

Introduction

Measurement of chlorophyll content of corn leaves using a meter offers an opportunity to evaluate the N status of actively growing plants without costly delays. The use of a chlorophyll meter has been previously evaluated for the ability to predict plant N status in dryland winter wheat (Follett, Follett, and Halvorson, 1992), rice (Turner and Jund, 1991), and to predict sidedress N requirements for dryland corn (Piekielek and Fox, 1992).

The chlorophyll meter is a hand held device that measures the transmittance at two wavelengths within an intact leaf. The meter calculates a numerical value which is proportional to the amount of chlorophyll present in the leaf. Since the chlorophyll content of plant leaves is directly related to the nitrogen supply of the plant, a chlorophyll meter may be useful in determining the nitrogen status of the plant. The objective of this study was to determine the ability of a chlorophyll meter to measure corn N stress at 3 input management levels and to determine if there is a correlation between chlorophyll meter readings and yield.

Materials and Methods

The ability of the chlorophyll meter to measure N stress was evaluated on three crop rotations (corn/corn, soybean/corn, and alfalfa/corn) and three management levels at the USDA Research Farm near Brookings, SD. Nitrogen management of low, integrated, and

high levels were determined by soil test recommendations with N fertilizer applied at 0, 50, and 100% of the recommended lbs N/ Acre (Table 1). Weed management treatments which were included are pre- and post-emergence herbicide for high management treatment, pre- and/or post-emergence herbicide if needed for the integrated management treatment, and no herbicide for the low management treatment. Each treatment was replicated three times.

Chlorophyll readings were recorded on the most fully expanded leaf at the 6- and 10-leaf stages of corn for 40 plants. These 40 leaves were collected, dried, weighed, and analyzed for total N. In addition to the 40 leaves, chlorophyll readings for the most fully expanded leaf of fifteen plants were recorded, above ground stover sampled, dried, weighed, and analyzed for total N at the 6- and 10-leaf stages. Relative chlorophyll was calculated by dividing the individual chlorophyll meter readings by the optimum chlorophyll reading for the particular rotation. Plant yields were recorded at physiological maturity.

Results and Discussion

Crop rotation and management levels influenced corn yields (Table 2). Management levels greatly affected yields in the continuous corn rotation, while they had little effect upon yields in the alfalfa/corn rotation. At the low management level, the alfalfa/corn rotation yielded similar to the high and integrated management levels whereas the soybean/corn and corn/corn rotations showed great differences between low and integrated management levels.

Average chlorophyll readings were influenced by crop rotation at the 6- and 10-leaf stage (Table 3). At the 6-leaf stage, average chlorophyll readings for the soybean/corn rotation were higher for all management levels when compared to other rotations. In the

corn/corn and alfalfa/corn treatment chlorophyll reading decreased with decreasing management intensity.

Grain yields from individual plots were correlated to relative chlorophyll ratios at the 6-leaf stage (Fig. 1). Treatments with the lower relative chlorophyll ratio corresponded to treatments with the lower yields while treatments with the higher relative chlorophyll ratios had the higher yields.

At the 10-leaf stage, average chlorophyll readings were similar for the different crop rotations in the integrated and high management treatments. However, in the low management treatment, chlorophyll meter readings were lower for the corn/corn and alfalfa/corn rotations than the soybean/corn rotation.

Generally, treatments with the highest yields had the highest chlorophyll reading (Tables 2 and 3). In the soybean/corn rotation, the actual chlorophyll readings remained consistent whereas yields were lower for the low management treatment compared to the high management treatment. In the alfalfa/corn rotation, the actual chlorophyll readings were lower for the low management treatment compared to the high management treatment whereas there was no yield difference between management treatments. From field observations, it was obvious that the dramatically low yields for the low management treatment of the soybean/corn and corn/corn rotation were affected by intense weed pressure as well as low fertility levels.

Using a chlorophyll meter to determine plant N status looks questionable from this study. However, these results have been influenced by a fertility and weed management interaction. In the alfalfa/corn rotation which had little weed pressure, the chlorophyll meter

showed a decrease in chlorophyll meter readings and yields as management intensity declined. In the corn/corn and soybean/corn rotations, the 45.8 and 67.8 bu/A yield decrease from the integrated to low management treatment may have resulted from the intense weed pressure and competition for light and nutrients between weeds and the corn plants.

The chlorophyll meter readings correlated with the final yield of corn. Correlation of total leaf N and chlorophyll readings may support further use of the chlorophyll meter to provide an in-field method of determining plant N.

Research being conducted in other states in addition to research described in this report suggest that further research into evaluating the chlorophyll meter for predicting 6-leaf N status is justified. This technology will give the farmer an opportunity to adjust the amount of N fertilizer applied at the 6-leaf stage, potentially reducing total N fertilizer applied and costs, as well as decreasing the opportunity of N leaching and contamination of ground water.

References

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Table 1. Crop rotations and amount of N fertilizer applied for management levels, USDA Research Farm, Brookings, spring 1992.

Rotation	Applied N Fertilizer		
	High	Integrated	Low
	-----lb N/ A-----		
Corn/Corn	76	34	0
Soybean/Corn	76	34	0
Alfalfa/Corn	34	0	0

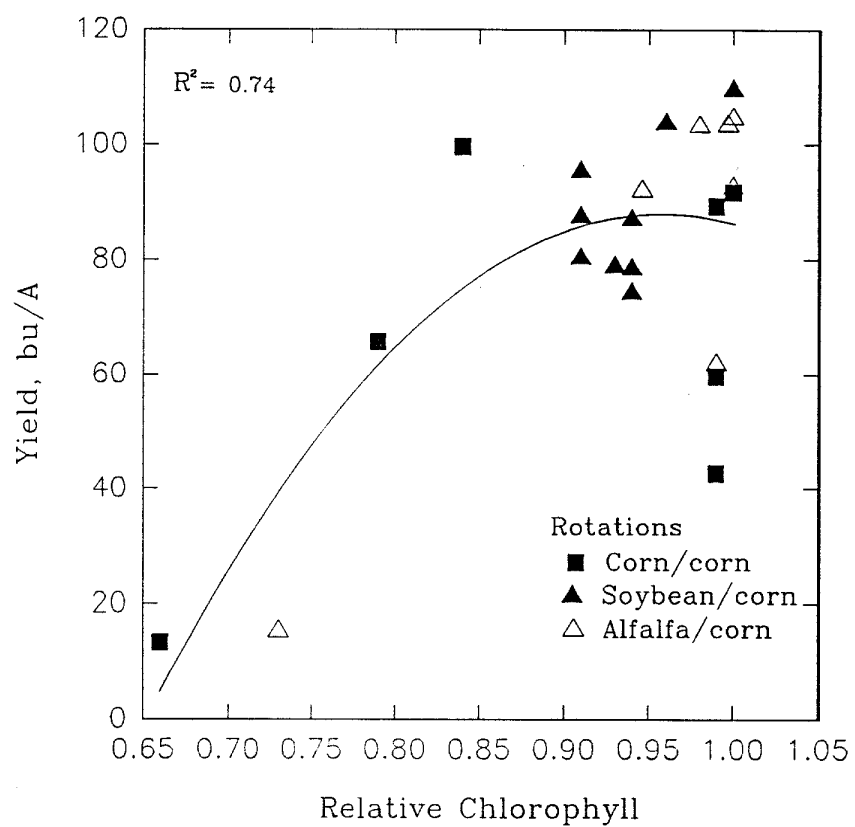
Table 2. Corn yield as influenced by crop rotation and management input levels.

Rotation	Management Level			
	High	Integrated	Low	LSD _{.05}
	-----bu/A-----			
Corn/corn	93.5	56.0	10.2	18.9
Soybean/corn	103.8	82.2	14.4	24.2
Alfalfa/corn	97.5	87.7	80.0	NS
LSD _{.05}	NS	NS	12.8	

Table 3. Average chlorophyll meter readings and relative chlorophyll levels at the 6- and 10-leaf stage.

Rotation	Actual Chlorophyll Reading			Relative Chlorophyll		
	High	Integrate	Low	High	Integrate	Low
6-Leaf Stage						
Corn/Corn	47.70	46.75	44.35	1.00	0.98	0.93
Soybean/Corn	51.62	51.42	51.58	1.00	0.99	0.99
Alfalfa/Corn	49.88	49.18	45.67	1.00	0.98	0.91
10-Leaf Stage						
Corn/Corn	55.44	52.78	44.60	1.00	0.95	0.80
Soybean/Corn	55.87	54.64	54.14	1.00	0.98	0.97
Alfalfa/Corn	55.97	54.82	47.22	1.00	0.98	0.84

Fig. 1. Yield Compared to Relative Chlorophyll at 6 Leaf Stage



1992 Weed Science Update

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Material and Methods

Weed monitoring and yield from alfalfa plots in the 4-year rotation. Alfalfa was established with wheat as a nurse-crop in the four year rotation. The alfalfa/wheat was planted into three management input levels; high, integrated, and low input. High input refers to plots that received recommended fertilizer levels and both pre- and postemergence herbicides. Integrated input refers to plots that received a percentage of the recommended fertilizer and preemergence herbicide if needed (determined by weed seed counts taken in the spring) or postemergence herbicide if needed (determined after scouting the plot area). Low input plots did not receive any fertilizer or herbicide inputs. These input levels on the plots have been in place since 1990.

The composition of the forage taken at each cutting was determined by clipping 10 circular 2.2 m² quadrats per plot and separating the forage into alfalfa, grasses, and forbes. Each component was dried separately at 110 C to constant moisture and samples were weighed. Data from two establishment years are reported. In the establishment year, the plots are sampled after wheat harvest. One set of establishment year plots was sampled on August 27, 1991 and a second set on September 1, 1992. One set of second-year hay plots was cut three times during the 1992 season; June 2, July 8, and September 1. The second-year hay plots in 1992 were the 1991 establishment plots. Each input treatment level was

replicated three times. Weights of the forage components were averaged over the 10 clipped areas and are reported in g m^{-2} .

Weed monitoring and yield from continuous corn and corn in the 4-year rotation. Weed seedling counts were taken in mid-June in the corn plots in the continuous corn study and in the corn plots that are part of the 4-year rotation (alfalfa-wheat/alfalfa the previous 2 years). Weed seedlings were identified and counted in 10 quadrats (25 by 40 cm) in the row for the rotation study and in 5 quadrats of the same dimensions in the continuous corn plots. Both the continuous corn and rotational corn plots are managed with three input levels of herbicides and fertilizer as described above and have three replications per input level.

Results and Discussion

Weed monitoring and yield results from alfalfa plots in the 4-year rotation. In the alfalfa establishment year, forage yield was minimal (Table 1). In 1991, the average forage yield for establishment year alfalfa at all input levels was 10.8 g m^{-2} . Alfalfa made up 39% of the forage and grasses, predominately yellow and green foxtail (*Setaria glauca* and *S. viridis*), made up 46% of the forage in the low input plots. In the high input plots, alfalfa made up 55% and grasses made up 22% of the forage. In 1992, the average forage yield in the establishment year plots across all input levels was slightly higher, averaging 14.1 g m^{-2} . The composition of the forage was slightly different between the treatments. In the low input treatment, alfalfa accounted for 48% of the forage and grasses accounted for 52% of the forage. In the high input treatment, alfalfa accounted for 81% of the forage and grasses accounted for 19% of the forage.

In the second year alfalfa (establishment year 1991), forage yield averaged 22.4 g m⁻² (Table 2) across all input systems. In the first cutting alfalfa made up 100% of the forage yield. Grasses which were prevalent in the fall of 1991 did not germinate or were smothered by the alfalfa growth. The second and third cuttings of the second year alfalfa contained grasses (yellow and green foxtail) and forbes [common lambsquarters (*Chenopodium album*), common ragweed (*Ambrosia artemisiifolia*), common sunflower (*Helianthus annuus*), common cocklebur (*Xanthium strumarium*) and wild buckwheat (*Polygonum convolvulus*)]. However, the grasses accounted for only 2% and the forbes accounted for only 3% of the forage in the last two cuttings. The amount of weeds present in the low input second-year alfalfa was much lower than in other low input systems at the East Dakota farm. Second-year alfalfa was acting as a smother crop by not allowing the weeds to establish due to the competitive effects of the crop.

Weed monitoring and yield results from continuous corn and corn in the 4-year rotation. In both the continuous corn and 4-year rotation, broadleaf and grass species were controlled by herbicide application in the high and integrated input plots (Table 3). There were a few more grasses present in the integrated plots of the 4-year rotation compared to the integrated input of the continuous corn. Yellow and green foxtail were the most predominant weeds present in both the continuous corn and rotational plots. Barnyardgrass (*Echinochloa crus-galli*) also was present in the plots but made of less than 5% of the total density. In the low input continuous corn plots, yellow and green foxtails averaged 77 plants m⁻² in the row, while the 4-year rotational corn plots averaged only 6 foxtail plants m⁻².

The most predominant broadleaf weeds in the plots included common lambsquarters, common ragweed, common sunflower, common cocklebur and wild buckwheat. Common milkweed (*Asclepias syriaca*) and hemp dogbane (*Apocynum cannabinum*) were also present in the plots. These broadleaves were present at a much lower density than the grass species, however, this complex of broadleaf weeds has been documented to greatly reduce yield and interfere with harvest operations. Once again, the herbicide applications in the high and integrated level of both rotations controlled the broadleaf weeds. The low input system of the continuous corn exhibited the greatest broadleaf density. The corn following alfalfa had broadleaf weed density comparable to the integrated input level.

Yields from the high input continuous corn and rotation plots were similar (Table 4). Corn in the integrated rotational plots had a higher yield than the continuous corn plots. The low input continuous corn plots had yields that were extremely low, while corn yield in the low input rotation plots was similar to the high and integrated treatments for that system.

These data suggest that corn may be grown in extremely low input systems without significant yield losses if effective rotational systems are established. The rotational system must be effective in controlling weeds and insects and maintain adequate fertility for the corn crop. Relying on cultivation alone in the continuous corn plots did not control weeds in that system. However, the weeds in plots following alfalfa were adequately controlled due to the smother crop effect of the alfalfa. The alfalfa has fewer weeds and therefore the seed bank for easily germinable seeds such as green and yellow foxtail and common sunflower have been reduced. Plowing the alfalfa the fall previous to corn planting also enhanced the fertility level of the soil. Corn in all input levels following alfalfa appeared to be normal.

Corn in the low input continuous corn rotation was yellow, spindly, and had a high percentage of barren ears. Although the 4-year rotation system (wheat-alfalfa/alfalfa/corn/soybean) may not be effective for all growers, special areas where limited inputs of herbicide and fertilizer are desired, such as groundwater protection zones, may benefit from the development of this type of rotation.

Table 1. Composition of forage biomass (alfalfa, grasses, and forbes) in alfalfa establishment years, 1991 and 1992.

Input level	1991			1992		
	Alfalfa	Grass ¹	Forbes ²	Alfalfa	Grass	Forbes
-----g m ⁻² -----						
Low	4.7	5.5	1.7	6.4	7.0	0.8
Integrated	4.0	5.3	2.2	7.8	4.0	0.4
High	4.9	2.0	2.0	12.6	2.9	0.3

¹ Grass species included yellow and green foxtail (*Setaria glauca* and *S. viridis*, respectively).

² Forbes included common lambsquarters (*Chenopodium album*), common ragweed (*Ambrosia artemisiifolia*), common sunflower (*Helianthus annuus*), common cocklebur (*Xanthium strumarium*) and wild buckwheat (*Polygonum convolvulus*).

Table 2. Composition of forage biomass (alfalfa, grasses, and forbes) in second-year alfalfa cut June 2 (first cut), July 8 (second cut), and September 1 (third cut), 1992.

Input	First cut			Second cut			Third cut		
	Alfalfa	Grass ¹	Forbes ²	Alfalfa	Grass	Forbes	Alfalfa	Grass	Forbes
-----gm ² -----									
Low	20.5	0	0	22.9	0.5	0.2	21.0	0.8	0.9
Inter	20.5	0	0	22.8	0.1	0.9	21.1	0.7	0.9
High	21.3	0	0	21.9	0.1	0.1	22.9	0.4	1.2

¹ Grass species included yellow and green foxtail (*Setaria glauca* and *S. viridis*, respectively).

² Forbes included common lambsquarters (*Chenopodium album*), common ragweed (*Ambrosia artemisiifolia*), common sunflower (*Helianthus annuus*), common cocklebur (*Xanthium strumarium*) and wild buckwheat (*Polygonum convolvulus*).

Table 3. Weed seedling densities in corn plots for the continuous corn and rotational study, June, 1992.

Input level	System	Foxtail ¹	Broadleaves ²	Alfalfa
		-----no. m ⁻² ----		-----
Low	Continuous corn	77	9.7	
	Rotation	6	0.7	0.7
	LSD _(0.05)	52	5.2	
Integrated	Continuous corn	1.4	1.7	
	Rotation	5.9	0.7	0.2
	LSD _(0.05)	2.2	ns	
High	Continuous corn	0.1	0	
	Rotation	0.5	0.2	0.3
	LSD _(0.05)	ns	0.1	

¹ Foxtails included both yellow and green foxtail (*Setaria glauca* and *S. viridis*, respectively).

² Broadleaf weeds included common lambsquarters (*Chenopodium album*), common ragweed (*Ambrosia artemisiifolia*), common sunflower (*Helianthus annuus*), common cocklebur (*Xanthium strumarium*) and wild buckwheat (*Polygonum convolvulus*).

Table 4. Corn yield in the continuous corn and rotational study, 1992.

Input level	System	Yield Bu/A
Low	Continuous corn	10.2 b ¹
	Rotation	80.0 a
Integrated	Continuous corn	56.0 b
	Rotation	87.7 a
High	Continuous corn	93.5
	Rotation	97.5

¹ Means followed by letter within the paired comparison are significantly different at the P=0.05 level.

Monitoring Populations of Ground Beetles (Carabidae) in Tillage/Rotation Plots

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Populations of ground beetles (Coleoptera: Carabidae) were monitored during the growing season by means of pitfall traps. Objectives of the study were to characterize seasonal cycles of potentially beneficial ground beetles, and to determine whether ground beetles are associated with particular crops, rotational sequences, or level of farming input.

Materials and Methods

One pitfall trap was placed in the approximate center of each plot. To prevent permanent impact on population density of ground beetles, traps were active for only 48 hr at biweekly intervals. When not in use, the traps were covered with plastic Petri plates to prevent undue impact on carabid populations in the plot area and to keep rainfall and soil out of the containers. Collections began the week of 29 June 1992 and continued until the week of 24 August 1992.

Results and Discussion

There were 22 carabid species collected during the season (Table 1). Four species, tentatively identified as Evarthus sodalis, Harpalus compar, Poecilus lucublandus, and Placidum agonum, comprised about 80% of the total collected. The highest incidence of all species occurred during the first two biweekly collection periods. In collections from all

corn plots, only numbers of H. compar varied significantly with rotation and farming input, among the four species mostly frequently collected. Occurrence of this species was greater ($p < 0.05$) in low input plots than in the higher input plots and it was more frequently collected from continuous corn and corn in a corn-soybean rotation ($p < 0.05$) than from corn in other rotations. In soybean plots, collections of E. sodalis and H. compar were higher ($p < 0.05$) in low input systems than in integrated or high input systems. There was no rotation effect on any of the four most frequently encountered species in soybean. Other crops, i.e. grain or alfalfa, had no statistically significant effect on numbers of carabids collected. The data suggest an association of these particular species with low input plots of corn or soybean but an ecological explanation for the effect is not immediately obvious.

Monitoring of ground beetle populations in the tillage plots will continue during 1993 but trapping will be extended over a greater portion of the growing season and intensified to better monitor early and late seasonal cycles in adult carabid activity. Pitfall traps will be placed in the field earlier in the season, about mid-April, and will remain in place until harvest. The collection interval will continue to be 48 hours but traps will be active on a weekly rather than biweekly schedule.

Table 1. Total collections during 1992 of species of Carabidae from tillage/rotation/input plots on the Eastern South Dakota Soil and Water Research Farm.

<u>Species</u>	<u>Number Collected</u>
<i>Abacidus permundus</i>	12
<i>Agonoderus leonti</i>	1
<i>Amara latior</i>	1
<i>Anisodactylus sericeus</i>	2
<i>Bembidion quadrimaculatum</i>	6
<i>B. patrule</i>	6
<i>Brachinus cordalis</i>	4
<i>Calathus gregarious</i>	1
<i>Calosoma calidum</i>	2
<i>Evarthus sodalis</i>	197
<i>Harpalus compar</i>	131
<i>H. erraticus</i>	3
<i>H. erythropus</i>	12
<i>H. funerarius</i>	1
<i>H. pleuriticus</i>	3
<i>Nebria pallipes</i>	6
<i>Platynus melanarius</i>	1
<i>Placidum agonum</i>	36
<i>Poecilus lucublandus</i>	37
<i>Scarites substriatus</i>	6
<i>Tripectrus rusticus</i>	1
<i>Tachys inornatus</i>	3

An Insect-Parasitic Nematode for the Suppression of Corn Rootworms

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Materials and Methods

The insect-parasitic nematode Steinernema carpocapsae (Mexican strain) was provided by "biosys", a biological pest control company, Palo Alto, CA. Two nematode suspensions (108,000 and 214,000 nematode infectives per 30.5 cm of row) and a control (no nematodes) were tested in the 3 integrated continuous corn plots on the farm. Each plot was divided into 3 equal sections and one treatment was applied to each section. The suspensions were dribbled along each row in 2 passes using a modified plot tractor. The applications were made on 24 June when the corn rootworm larval populations was determined to be mostly in the 2nd stage. Soil samples were taken from the treated rows on 25 June and 8 July. A bioassay was used to determine if nematodes were present in the soil samples. Two corn rootworm emergence cages were placed in each plot section and the number of emerging adult western and northern corn rootworms were counted until 9 September. Six rows of each section in all plots were harvested and the total grain weight was determined and adjusted for differences in moisture and row length.

Results

Bioassays on the soil samples indicated that nematodes were present at both sampling times (24 June and 8 July), however, the second assay period produced a lower mortality

response (probably fewer nematodes survived to this time). Adult emergence and yield data are as follows:

Treatment	Average Number Western Corn Rootworm	Average Number Northern Corn Rootworm	Yield Bu per Acre
Control	48 \pm 36	20 \pm 10	56
108,000 nematodes	30 \pm 40	9 \pm 11	52
214,000 nematodes	30 \pm 19	17 \pm 8	60

While there appear to be trends in the data to suggest that the nematode applications affected adult emergence and yield, none of the treatments were statistically significant for adult emergence or yield.

Discussion

The bioassay information suggests that some portion of the original nematode population was present in the treatment zone fourteen days after the application. Considering that the surface of the soil in the plots was very dry, the surface soil temperature on the day of the application was near 40 C in the sun and 32 C in the shade, and 32-35 C is lethal to these nematodes, nematode persistence for fourteen days was unexpected. With improvements in application techniques, nematode persistence might be improved. The trends in the data for reduced adult emergence and increased yield are encouraging. Improved application techniques and more extensive sampling will be needed to fully evaluate the potential of this biological control approach for corn rootworm control.

Surface Compaction as Affected by Tillage and Landscape Position

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Problem

Soil compaction has been shown to be a potential crop production problem in the northern climatic zone. Field traffic with high axle load vehicles increase soil bulk density, increase soil strength, and reduce pore volumes. The reduction in pore volumes occur primarily in the macropores. These changes can exert a negative influence on soil aeration, root exploration, and water and nutrient uptake. Although concerns about soil compaction are justified as demonstrated by research with high axle load vehicles, the extent of the problem may be exaggerated. It is the purpose of this project to evaluate the effect of spring field traffic associated with the planting operation with standard field equipment on soil compaction as influenced by landscape position and management systems.

Approach

Field plots were established in 1990 across the landscape starting from the summit position across the backslope (both positions with good surface and internal drainage) and through the toeslope position (poor surface and internal drainage). Soil series included in this transect are: Vienna loam (1-3% and 3-5% slopes), Deep Vienna loam (3-5% slope), Spottswood loam (1-3% slope), and Lismore silty clay loam (0-1% slope). Tillage systems used were moldboard plow, chisel plow, ridge till, and no-till. Crop rotations were

continuous corn and corn-soybeans. Compaction variables are wheel traffic on one side of the planted row, both sides, both sides three times, and no wheel traffic on either side. Wheel traffic was applied with a 130 hp tractor with a rear axle load of 6.5 tons. Soil measurements taken will be used to categorize soil strength, pore volumes and pore size distribution.

Accomplishments

This is the second complete year into the project. Bulk density increased with field traffic with a corresponding increase in penetrometer resistance. Pore volumes decreased with the major decrease occurring in macropore volumes. The surface compaction variable has only had minimal influence on crop yields. Yield variations due to landscape position has been observed and can be correlated with depth of topsoil and drainage. As the mollic depth (topsoil) decreases (shoulder position and upper backslope) yields decrease and as surface and internal drainage decrease (toeslope position) yields decrease. An additional yield decrease was observed with the greatest compaction variable (both sides, three times) in the toeslope position, but significance of this yield reduction has not been analyzed. Tillage systems also have not influenced yield.

Interpretation

Results obtained at this stage of the project suggest that surface compaction resulting from normal spring traffic patterns with standard field equipment is not detrimental to crop production under climatic conditions experienced thus far. The additional yield reduction observed with the high compaction variable in the toeslope position suggest that compaction

problems may develop over time in certain landscape positions. Soil series in the toeslope position is the Lismore silty clay loam with poor internal and surface drainage. Tillage and field work is commonly done on this soil series under wetter than desirable conditions. This is the condition when soils are most susceptible to compaction.

Future Plans

These trials will be continued to monitor changes in soil surface physical properties resultant from tillage management and surface compaction variables as influenced by surface compaction. Root growth patterns will be measured in the future as physical properties begin to stabilize.

Corn Rootworm Larval Feeding Effects on Plant Characteristics

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Corn rootworm larvae account for over a \$1 billion loss to U.S. maize producers in terms of yield reduction and insecticide treatment costs each year. Soil insecticides targeted against corn rootworm larvae are applied annually to 50 to 60 percent (12 to 16 million ha) of the U.S. maize acreage. Increased public awareness of the detrimental effects of pesticides on nontarget organisms, water quality, user health, and greater interest in sustainable agriculture production systems may become the driving forces behind major changes in maize production systems in the near future. Consequently, research into management practices that help plants tolerate rootworm larval damage is and will continue to be an important priority.

Because of these economic and environmental ramifications and because pest-tolerant plants offer an attractive alternative to insecticides for limiting crop losses, considerable effort has been focused on genetic improvement of maize tolerance to corn rootworm larvae. Two mechanisms of plant resistance to rootworm larvae feeding, tolerance and antibiosis, have been described. A tolerant plant sustains as much feeding damage as a susceptible plant but is able to grow and produce high grain yield in spite of the damage. Tolerance is thus related to root system size; the larger the root system, the more tolerant the plant is to rootworm feeding damage. Vertical root pull resistance has been used to measure root system size and to measure root damage caused by corn rootworm larvae. Antibiosis is

defined as the inherent ability of the plant to adversely affect the insect, which in turn causes the insect to avoid the use of that particular plant as a host. Root damage ratings which are a measure of the amount of root tissue eaten by rootworm larvae, can be used as a measure of antibiosis.

Two studies were conducted to determine if progress has been made in breeding tolerance to Western corn rootworm larval feeding into maize hybrids and to determine the mechanism(s) of that tolerance, and to develop new root/soil sampling technology to aid in understanding the "black box" interactions between a soil-dwelling insect and the host plant.

Study 1. Assessment of Corn Rootworm Resistance and Tolerance in Experimental and Commercially-Available Corn Genotypes

During a visit with Dan Palmer, Entomologist with DeKalb Plant Genetics, Olivia, MN, the topic of host plant resistance to corn rootworm larvae was discussed. Two lines with potential resistance, RW 17 (Branson et al., Environ. Entomol. 12:1509) and NGSDCRW (Kahler et al., Crop Sci. 25:202), were crossed to create the hybrid RW 17 X NGSDCRW. We were interested in testing this hybrid under the controlled infestation protocol. Other lines of interest were the synthetic line NGSDCRW and commercially-available lines with varying degrees of "tolerance" from DeKalb Plant Genetics.

Materials and Methods

A small field experiment was conducted during the summer of 1992 at the Eastern South Dakota Soil and Water Research Farm. Data collected was root pull resistance at maximum damage (majority of rootworm larval population in pupae stage), root pull

resistance at 17 days past maximum damage, root damage rating (1-9 scale), lodging (% of plants leaning at greater than 30% from vertical), rootworm adult survival (% of viable eggs infested), and grain yield.

Results and Discussion

The 10 genotypes used in the experiment were artificially grouped into categories of tolerant/resistant, tolerant, and susceptible (Tab. 1). For clarity, the data were averaged by category, and presented in Figs. 1 through 4.

Root pull resistance in uninfested plants is approximately 20% greater in Tolerant and Resistant/Tolerant genotypes when compared with Susceptible plants (Fig. 1). This observation supports the contention that a large root system is related to the perception of "tolerance" to corn rootworms. As expected, corn rootworm infestation (maximum damage) reduced root pull resistance across all genotypes studied (Fig. 1). Seventeen days after maximum root damage, root pull resistances for all categories of genotypes were similar across 0 and 250 eggs per row foot infestation levels (Fig. 2). At higher infestation levels (500 and 1100 eggs per row foot) the trend of root pull resistance was Resistant/Tolerant > Tolerant > Susceptible, suggesting that larger root systems are better able to grow and proliferate under conditions of rootworm damage than smaller root systems.

The true test of resistance (antibiosis) would be the impact of genotype category upon root damage ratings and larval survival to adult stage. Resistant/Tolerant genotypes consistently showed lower root damage ratings than other genotype categories (Fig. 3). Of interest is the observation that Tolerant genotypes had lower root damage ratings than

Susceptible genotypes at 250 and 500 eggs per row foot. These results suggest that less root tissue was damaged by rootworm larvae in genotypes for the Resistant/Tolerant category.

Two possible reasons exist for this observation: 1) Larvae are repelled from eating the root tissue of these genotypes; 2) Root tissue from these genotypes is nutritionally superior to other genotypes, thus the larvae need to consume less root tissue to survive and develop.

Data concerned with larval survival to adult stage would help indicate which of these hypotheses most approximates the truth.

Survival to adult stage was greater in Resistant/Tolerant genotypes when compared to Tolerant and Susceptible genotypes at the infestation levels of 250 and 1100 eggs per row foot (Fig. 4). These results suggest that resistance (antibiosis) does not exist in the Resistant/Tolerant genotypes, and that the reason for decreased root damage ratings in these genotypes is due to nutritional superiority of this root tissue.

If corn producers had the option to use maize genotypes that are truly resistant (tolerance plus antibiosis) to rootworm larval feeding damage, they could reduce their reliance on soil insecticide application. More research into incorporating rootworm larval resistance into maize germplasm is therefore warranted.

Study 2. New Technology for Assessment of Corn Rootworm Larval Damage to Root Systems of Corn

The corn rootworm root damage rating-grain yield loss relationship has been shown to be inconsistent from year to year under different field environments. This inconsistency demonstrates the need for a greater understanding of how rootworms affect the root system of their hosts, and how this impacts the physiology of the plant. It has been suggested that

root damage ratings place too much emphasis upon the damage and removal of roots from the root system by the insect. Important aspects of the root system are neglected by root damage ratings, namely the amount of roots in the root system that are not damaged and the proliferation of lateral roots in moderately damaged root systems. Once rootworm damage is viewed using a standardized system that places proper emphasis upon the undamaged roots and lateral root proliferation, a stronger correlation between these root system characteristics and yield loss may become evident.

A new technology that provides morphological descriptions and analytical information of corn root systems under field environments has been developed through cooperative efforts between scientists at the Northern Grain Insects Research Laboratory and Plant Science Department at South Dakota State University. This new technology has been applied to experiments conducted at the Eastern South Dakota Soil and Water Research Farm as well as on privately-owned farms in Brookings County. This work has produced equipment to take soil samples that preserve the spatial distribution of root systems within the soil profile as well as rapid root system quantification protocols. This new technology, coupled with established root system evaluation technologies, will allow collection of unique and novel information about insect damage effects upon root system proliferation within the soil profile.

Materials and Methods

Field Experiment. The modified monolith technique was evaluated on Vienna loam soils (fine-loamy, mixed Udic Haploborolls) at the Eastern South Dakota Soil and Water Research Farm near Brookings, SD, in 1991 and 1992.

Monolith Sampling. A monolith soil sampler (Fig. 1), modified from the design of Walker et al. (1976), was placed across a maize row and centered as close as possible to the plant of interest. The sampler was manually driven into the ground with a post driver. Soil was excavated with a spade from three sides of the sampler to permit removal without disturbing the monolith sample. The soil monolith (76 cm long, 5.1 cm wide, and 30 cm deep) was removed from the sampler and placed on a board with nails spaced in a 5 cm grid pattern. Interspace between the nail board and the soil sample was a sheet of 1/2 inch hardware cloth. Monoliths were stored at 4 C in plastic bags.

Mapping Soil Monoliths. Soil monoliths were soaked overnight in a tank of water to saturate the soil. Monoliths were removed from the tank and pressure washed with a large volume of water. The water flow was provided by a fire hydrant connected to six spray nozzles. Washing continued until all of the soil was removed.

Graphics Procedures. Root characteristics were obtained for each soil monoliths by removing the hardware cloth containing the root systems from the nail-board, and recording the image using a camera. Root systems were photographed on a black background.

Results and Discussion

Application of soil monolith technology to studies designed to elucidate the relationships between corn rootworm feeding damage and root system morphology would increase understanding of this complex "black box". Figs. 2 through 5 present visual data obtained using the monolith technology that characterizes corn root system morphology at the VT (tassel) stage of plant development. Plants grown under corn-soybean rotation show the

undamaged appearance of the root system (Fig. 2). Controlled infestation of plants under a corn-soybean rotation with corn rootworm eggs (Fig. 3) results in a loss of the succulent large-diameter nodal root axes from the root system. This same root system appearance is seen in plants grown under continuous corn rotation (Fig. 4) suggesting that these plants suffered corn rootworm larval feeding damage. The influence of soil insecticide application upon root system damage is illustrated in Fig. 5. It is apparent that the insecticide did not totally eliminate damage to the nodal root axes outside of the "zone of protection".

However, within the "zone of protection", enough length of the nodal root axes was present to allow proliferation of lateral roots from the damaged axes. This insecticide-promoted lateral root proliferation may add to the complexity of the insect damage-grain yield-environment interactions, thus confounding any generalized conclusions of the impact of soil insecticides upon grain yield in any given year. Obviously, additional data is needed to resolve this dilemma.

Table 1. Genotype characteristics: Uninfested plants

Genotype	Category	Root Pull Resistance (Kg Plant ⁻¹)		Grain Yield (Bu/Acre ⁻¹)
		Pull 1 ^d	Pull 2 ^e	
RW17 x NGSDCRW	T/R ^a	136	212	12
NGSDCRW	T/R ^b	128	178	100
DK 447	T/R ^c	130	215	— ^f
DK 397	T	142	204	133
DK 547	T	127	208	129
DK 485	T	137	214	148
DK 415	S	90	191	115
DK 464	S	118	217	121
DK 524	S	106	176	124
DK 535	S	108	216	102

Symbols Denote: T = Tolerant; S = Susceptible; R = Resistant

^aBranson et al., 1983. Environmental Entomology 12:1509.

^bKahler et al., 1985. Crop Science 25:202.

^cPersonal Communication - D. Palmer

^dPlants sampled when rootworm populaiton was in pupae stage (maximum damage)

^ePlants sampled 17 days after maximum damage

^fIncomplete data for this genotype was due to low plant populations (poor germination)

Fig. 1 ROOT PULL RESISTANCE - MAXIMUM DAMAGE (KG/PLANT)

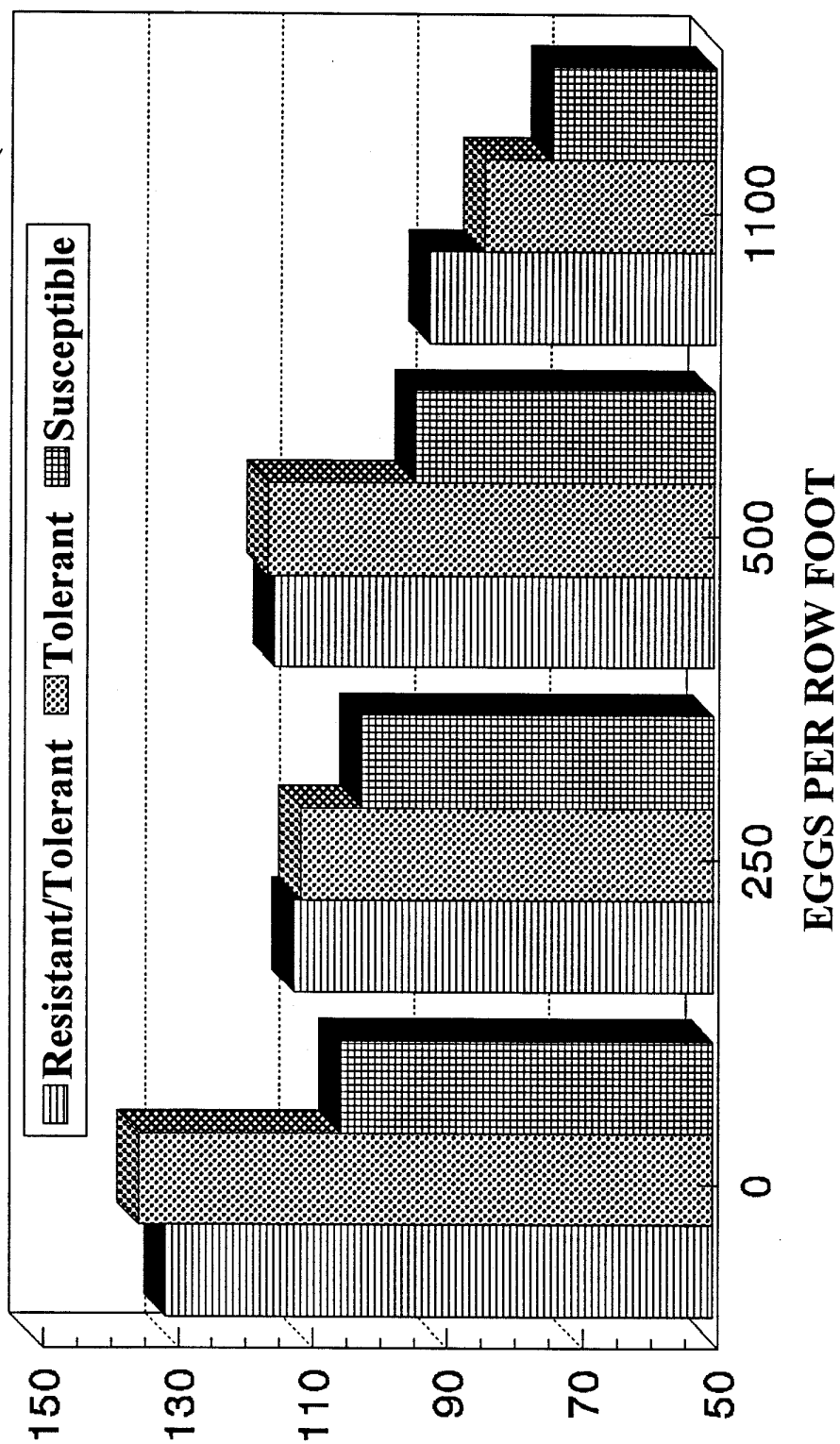


Fig. 2 ROOT PULL RESISTANCE - RECOVERY (KG/PLANT)

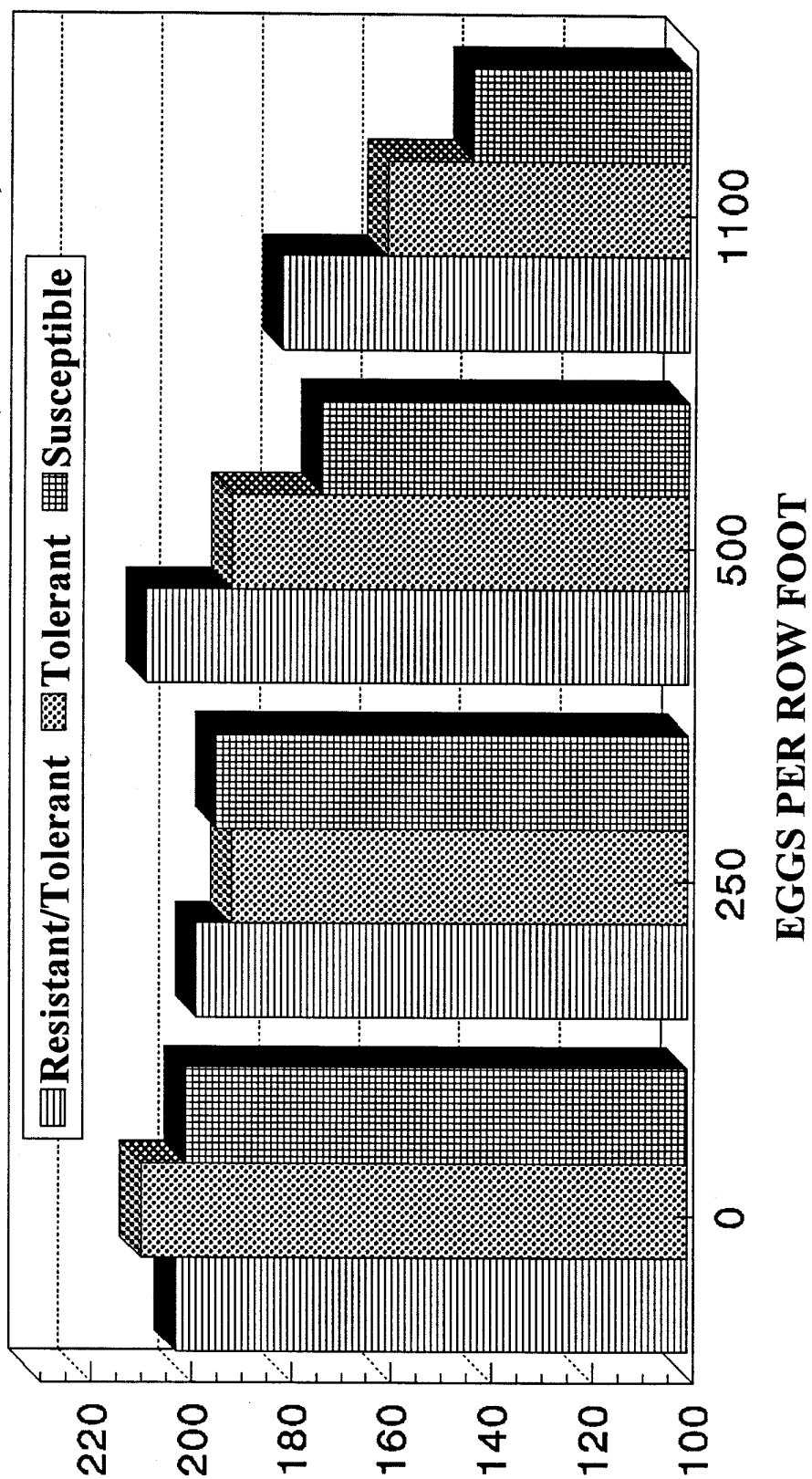


Fig. 3 ROOT RATINGS (1-9 SCALE)

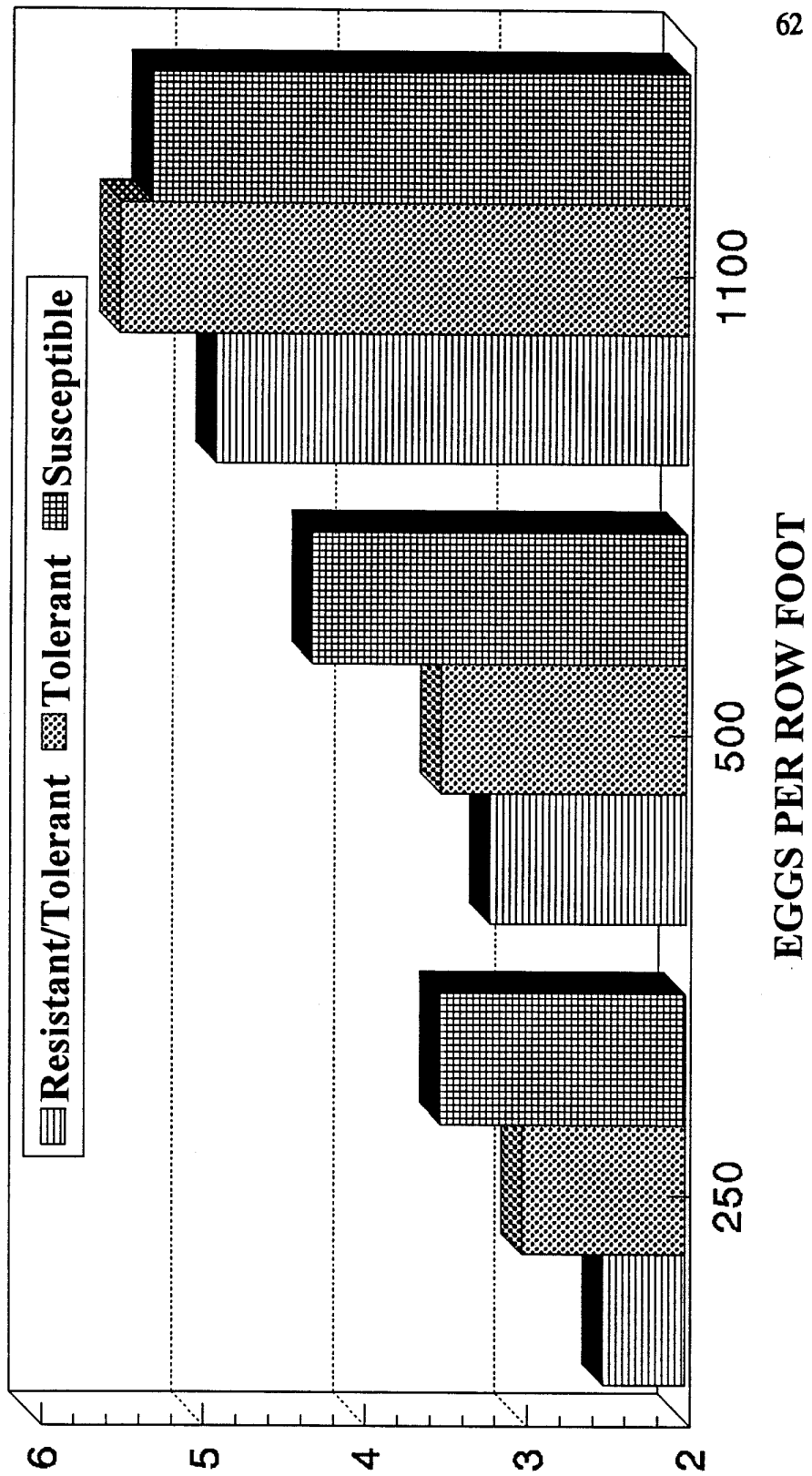
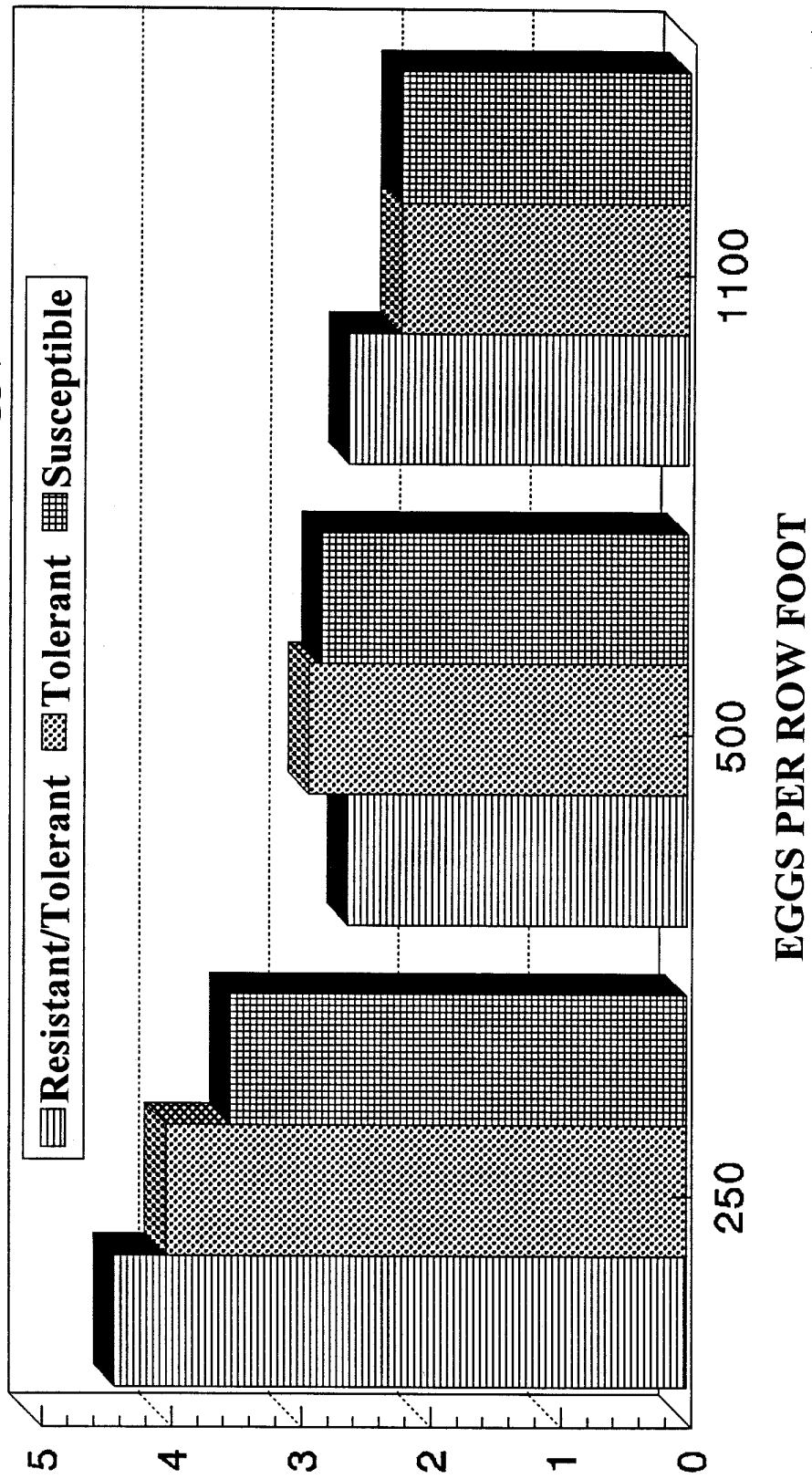


Fig. 4 SURVIVAL TO ADULT STAGE (% of viable eggs)



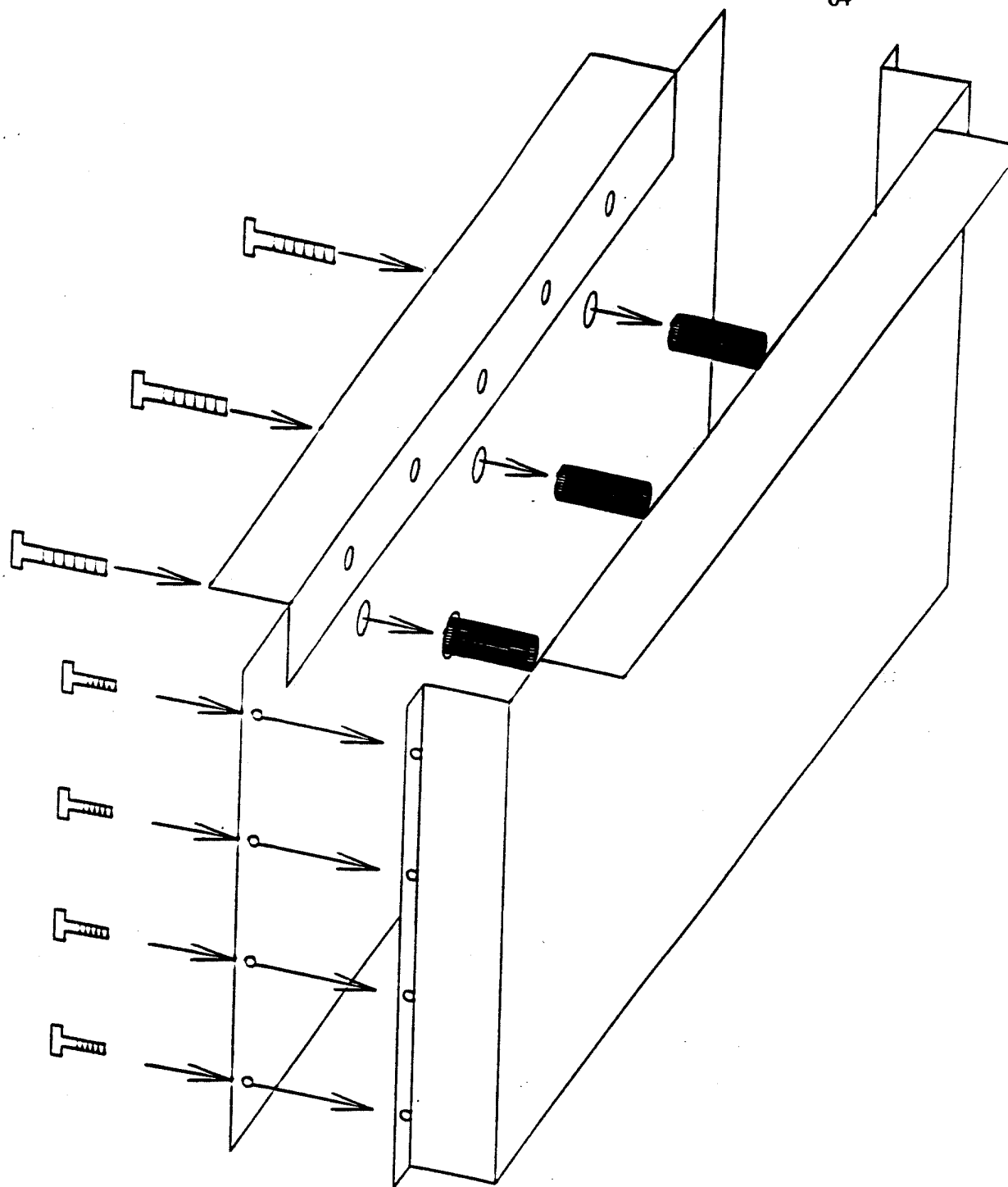


Fig. 1. Diagram of the modified soil monolith sampler. The front and back plates of the sampler were constructed with 32 mm steel plate. The top portion of the sampler was constructed from 64 mm wall, 640 x 640 mm angle iron. Sampler was assembled using nuts, bolts, and spacer sleeves positioned as shown. The outside dimensions of the sampler were 42 cm high x 84 cm long x 6 cm deep.

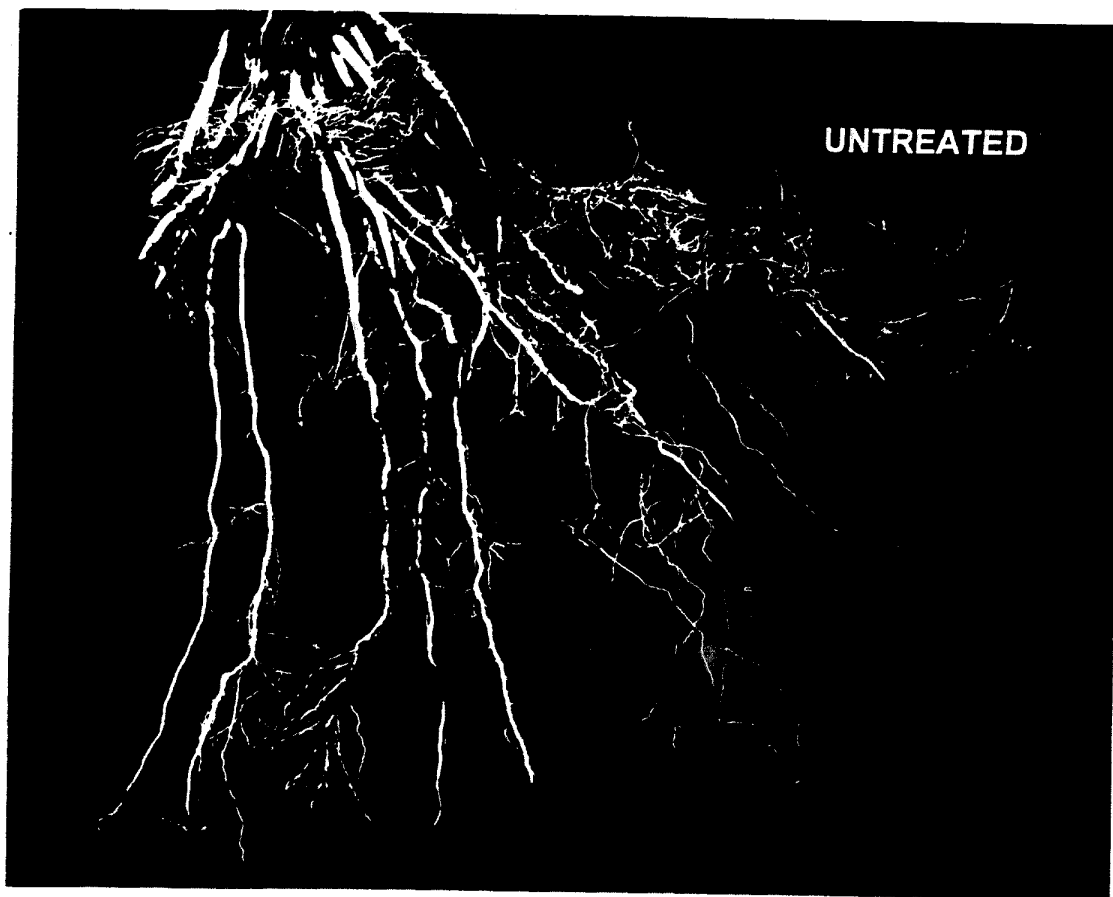


Fig. 2 Root system of a corn plant grown under corn-soybean rotation. The plant was in the VT (tassel) stage of development at the time of sampling. Note the abundance of the root system and the white appearance of the nodal root axes.

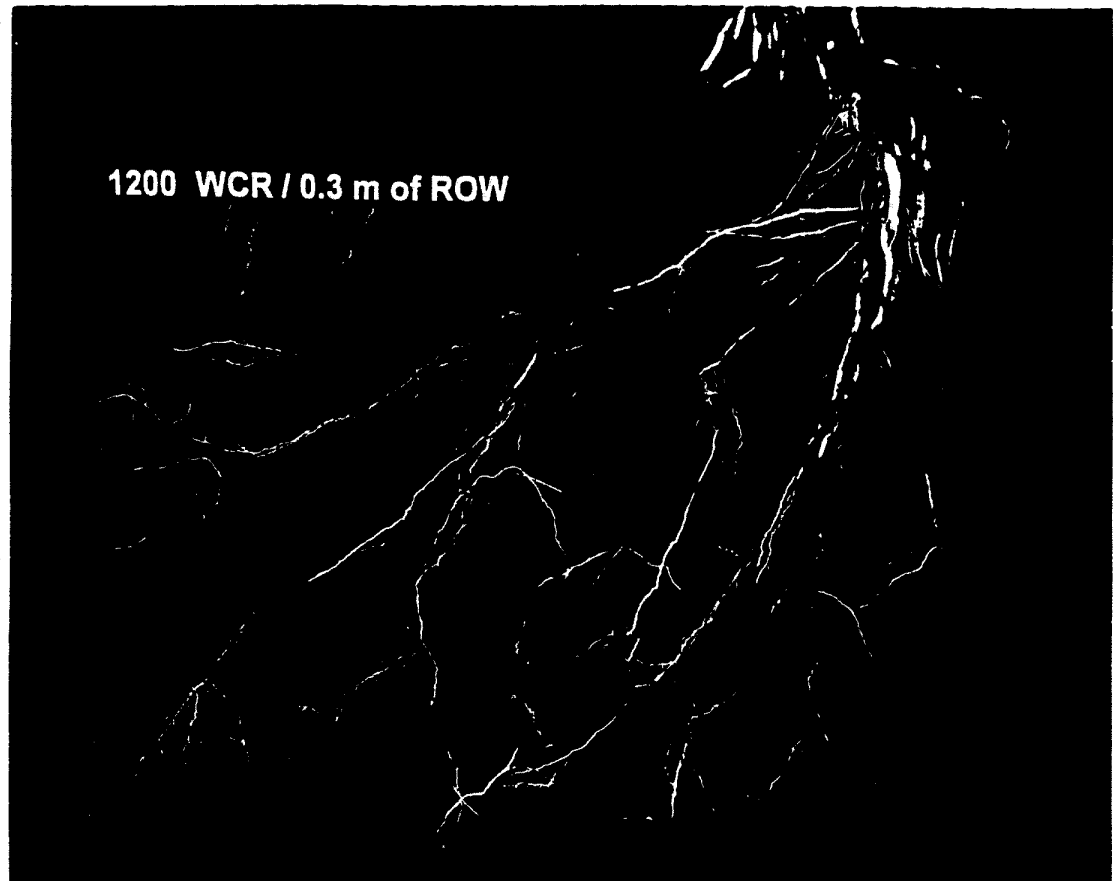


Fig. 3. Root system of a corn plant grown under corn-soybean rotation in the presence of 1200 Western corn rootworm eggs per foot of row. Note the absence of the white nodal root axes.

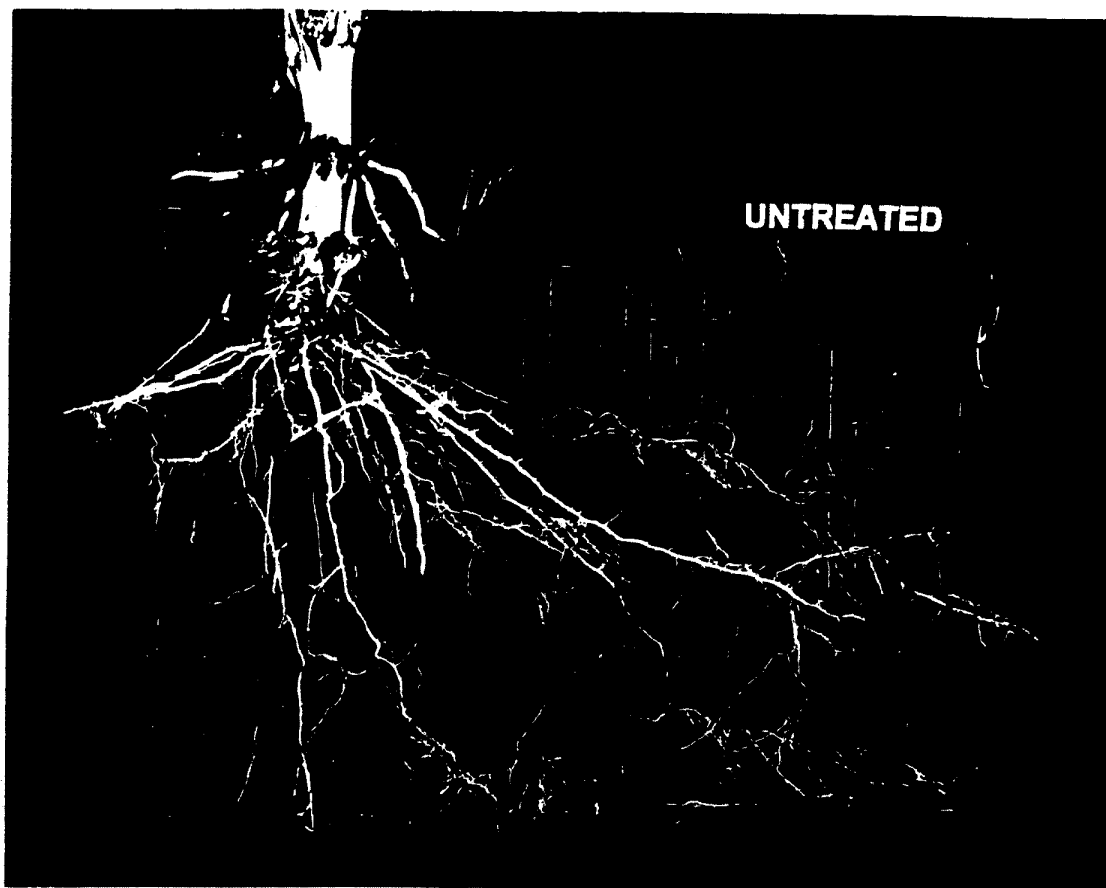


Fig. 4 Root system of a corn plant under continuous corn rotation. Note the similarity of the appearance of this root system to that of Fig. 3 above. The absence of the white nodal root axes indicates that corn rootworms have damaged those root axes.

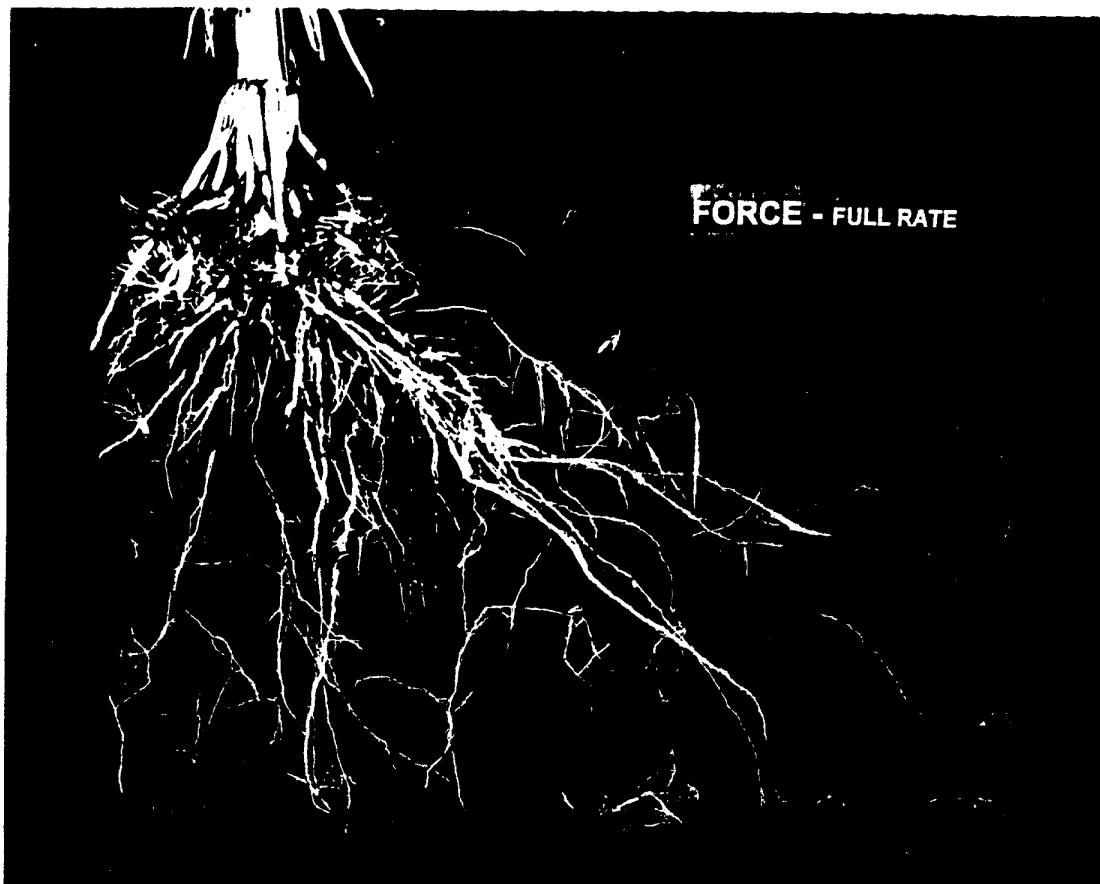


Fig. 5 Root system of a corn plant under continuous corn rotation plus application of full rate "Force" soil insecticide. Note that the white nodal root axes do not extend far beyond the base of the plant, suggesting that the corn rootworm larvae damaged the root systems of this plant in the region of the soil left unprotected by the insecticide.

Root Structure and Function in Long-Term Sustainable Crop Production Systems

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The long-term economic viability and environmental compatibility of agricultural production practices are foremost concerns of the public, farmers, and the scientific community. The widespread use of fertilizers and pesticides for agricultural production poses several significant and interdependent problems: 1) Non-point agricultural chemical contamination of groundwater supplies has the potential for catastrophic impact upon human health, wildlife, and the environment. 2) The high energy and economic costs associated with manufacture and use of fertilizers and pesticides fosters a chemical dependency syndrome that drives farmer decisions towards conventional production practices with the goal of increasing yields. As the deleterious environmental and economic consequences of conventional high-input farming practices continue to compound, the future of the family farm and the viability of our rural communities becomes increasingly more bleak. The sociological and economic upheaval occurring in our rural communities will undoubtedly worsen if we continue along our current course.

Sustainable agriculture can be defined as the effective and productive use of natural resources so that they are conserved or enhanced while still producing commodities. A basic tenet of sustainable agriculture is that the crop production systems used must be economically viable. One way to ensure economic viability is to exchange the chemical dependency syndrome of "maximum yield" for the sustainable agriculture trait of "maximum

profitability" in an environmentally responsible manner. Substitution of knowledge-based crop management protocols for conventional high-input production practices would achieve maximum profitability by minimizing off farm inputs.

There are also other important advantages of sustainable agriculture systems besides maximum profitability. These include maintenance of an optimal physical environment for topsoil nutrient availability, increased water infiltration into the root zone, increased ability of the soil to buffer short term environmental changes, and minimize contamination of surface and ground water. All of these advantages are inter-related and dependent at least in part on soil physical properties, soil organic matter levels, and soil nutrient relations.

The use of crop rotation as a substitute for fertilizer and pesticide inputs would go a long way in enhancing sustainability in agriculture production systems used in eastern South Dakota and western Minnesota, and would enhance within this region the environmental and natural resource base upon which a sustainable agricultural economy depends. A more thorough and complete understanding of how crop rotations affect crop growth and yield, with particular emphasis upon crop mineral nutrient relations, is needed as a base for measuring the economic feasibility of using crop rotations in sustainable agricultural systems. To achieve this end, experiments were conducted at the Eastern South Dakota Soil and Water Research Farm during the 1992 growing season.

Materials and Methods

Field Experiment. The experiment was conducted on the crop rotation/input plots which contained corn. Descriptions of the crop rotation treatments and the levels of chemical input

can be found elsewhere in this report. To review, crop rotation treatments include a continuous corn, a corn-soybean, and a corn-soybean-small grain/legume series. The plots were in their third year. Consequently, the continuous corn plots had three years of corn; the corn-soybean plots had corn the first, soybeans the second, and corn the third year; and the corn-soybean-small grain/legume plots had small grain inter-seeded with alfalfa the first year, alfalfa the second year, and corn the third year. Input level treatments were superimposed upon the crop rotation treatments. Input levels were characterized as "high", "integrated", and "low".

Data Collected. Plots were observed for corn and weed growth on June 18, 1992. Root systems were sampled using a modified monolith sampling unit (described elsewhere in this report) on June 25, 1992. Plots were photographed on July 29, 1992. Plants were harvested for dry weight determination and mineral nutrient content on August 8, 1992. Plots were harvested for grain yield as described elsewhere in this report.

Results and Discussion

Field Observations. The first observations of corn growth and weed levels in corn plots were taken on June 18, 1992. Without exception, the corn in the high input plots across all rotation treatments had good growth and virtually non-existent weed growth. Corn in the integrated input plots also had good growth, but there was a little of foxtail seedling growth in these plots (regardless of rotation treatments). Corn in the low input plots under continuous rotation or corn-soybean rotation looked terrible. The plants were obviously stunted and yellow (chlorotic) in color. Weed growth in these plots was so great so as to

make it hard to distinguish the crop plants. In contrast to this, the corn in the corn-soybean-small grain/legume rotation looked good. These plants were dark green in color and were developing nicely. Weed growth under this four year rotation was present in the form of some grass (foxtail) and dicot (sunflower) species. The weed growth was dwarfed by the growing corn canopy. Further information on weed counts and identification can be found elsewhere in this report.

Root System Structure. Root systems were sampled using the modified soil monolith method on June 25, 1993. In general, there were no obvious differences in root system structure across the rotation plots and the high and integrated input level treatments. Consequently, these photographs will not be presented here.

The most obvious differences in root system structure were seen in the low input plots across the rotation treatments. The corn root system was indistinguishable from the foxtail roots in continuous corn (Fig. 1b) and corn-soybean plots (Fig. 2b). In contrast to this, the corn root system in the corn-soybean-small grain/legume plots (Fig. 3b) was well developed and not bothered by competition from weeds. Organic matter was also present to a much greater extent in this rotation than the continuous corn or corn-soybean rotation.

Crop Canopy Growth. Observation of crop canopy growth on July 29, 1992 revealed no obvious differences across the rotation plots and the high and integrated input level treatments. In all of these plots, the crop canopy was complete over the inter-row space at this time. Consequently, weeds were being shaded by the crop.

The crop canopies for the low input continuous corn plots (Fig. 1a) and the corn-soybean plots (Fig. 2a) were not yet fully developed at this time. Consequently, ample

sunlight was available to power weed growth. In contrast to this, the crop canopy from the corn-soybean-small grain/legume rotation (Fig 3a) was fully developed.

Crop Growth and Nutrient Relationships. Plant dry weight measurements (Fig. 4) indicated that the high input treatments returned the largest plant shoot dry weights across all rotation treatments. The dry weights of plants grown under integrated input levels for the continuous corn and the corn-soybean rotations were smaller than those of plants grown under corn-soybean-small grain/legume rotation. This same relationship was seen for plants grown under low input. Indeed, the dry weight of plants grown under the low input corn-soybean-small grain/legume treatments were drastically higher than those grown under the other rotations.

Of all the plant mineral nutrients tested, only nitrogen concentration within the plant tissue appeared to be directly related to rotation and input level treatments (Tab. 1). Conversion of the nitrogen concentration data to a per plant basis (Fig. 5) reveals that the plants grown using the high input treatments contained the largest nitrogen levels across all rotation treatments. The nitrogen levels of plants grown under integrated input levels for the continuous corn and the corn-soybean rotations were smaller than that of plants grown under corn-soybean-small grain/legume rotation. This same relationship was seen for plants grown under low input, however, the nitrogen content of plants grown under low input corn-soybean-small grain/legume treatments were drastically higher than those grown under the other rotations.

Grain Yield and Nutrient Use Efficiency. Grain yield production under the rotation/input treatments differed drastically (Fig. 6). Plants grown using the high input treatments

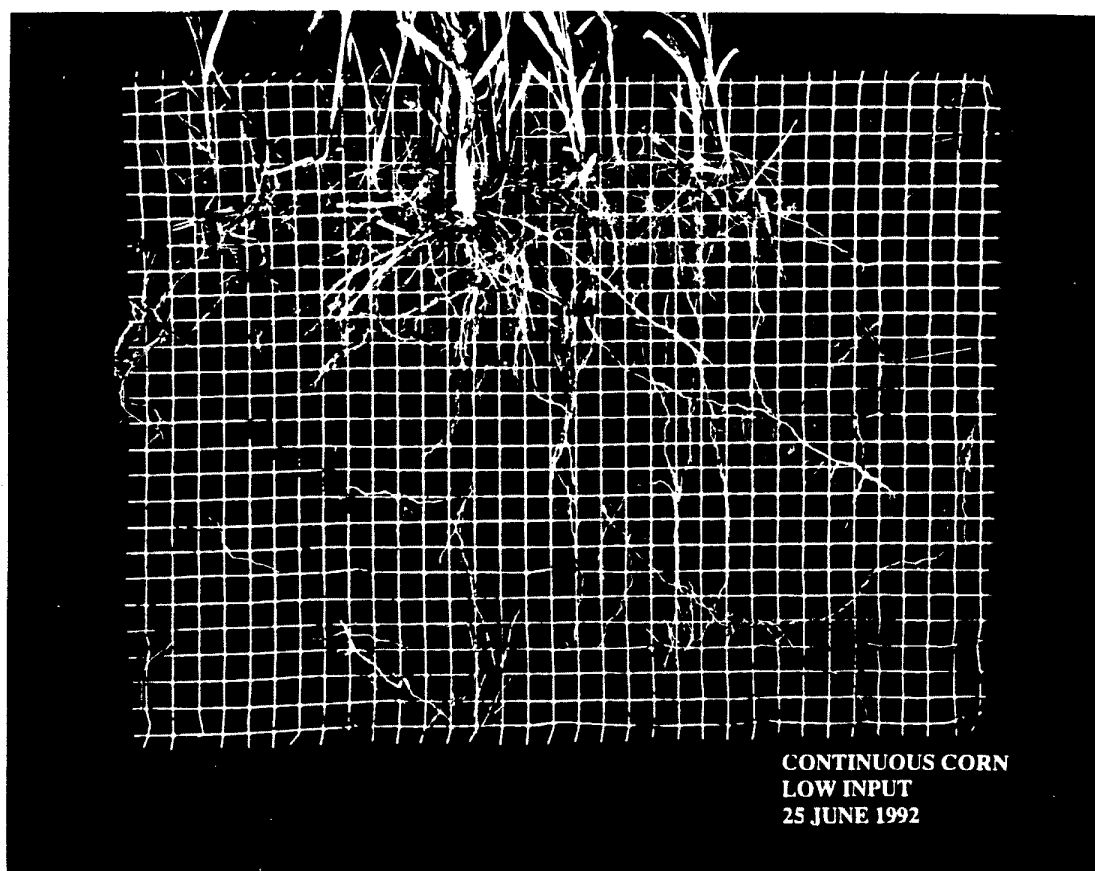
produced the largest grain yield across all rotation treatments. The grain yield of plants grown under integrated input levels for the continuous corn and the corn-soybean rotations were similar to that of plants grown under corn-soybean-small grain/legume rotation. Plants grown under low input in the continuous corn and the corn-soybean rotation hardly produced any grain yield at all. However, the plants grown under low input corn-soybean-small grain/legume treatments produce drastically higher yield than those grown under low input with continuous corn and corn-soybean rotations.

The concept of "critical concentration" is important in understanding how nutrient status in crops is related to grain yield. The critical concentration is that concentration of a nutrient in the crop tissue that is just below the level giving optimal yield. The concept is illustrated in Fig. 7. In the deficient zone, where nitrogen levels were below the critical concentration, grain yield increased sharply as the concentration of nitrogen in the crop tissue increased. Beyond the transition zone, nitrogen concentration is further increased by additional supplies of the nutrient in the soil, but the supply of nitrogen is no longer the factor that limits yield, which remains constant. As a result, the additional amounts of nitrogen absorbed raise the concentration of the nutrient in the tissue to levels of "luxury consumption". The results presented in Fig. 6 indicate that the corn-soybean-small grain/legume rotation, regardless of input level, did an admirable job in providing "just enough" nitrogen to the system to efficiently power grain yield production. The corn-soybean rotation at high input provided too much nitrogen (2 out of 3 times) to the plant to efficiently power grain yield production.

Fig. 1a (Top) Corn crop characteristics from a continuous corn rotation with low chemical inputs. Photograph taken July 29, 1992.

Fig. 1b (Bottom) Root system characteristics of a plant sampled from a continuous corn rotation with low chemical inputs.

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CONTINUOUS CORN
LOW INPUT
25 JUNE 1992

Fig. 2a (Top) Corn crop characteristics from a corn-soybean rotation with low chemical inputs. Photograph taken July 29, 1992.

Fig. 2b (Bottom) Root system characteristics of a plant sampled from a corn-soybean rotation with low chemical inputs.

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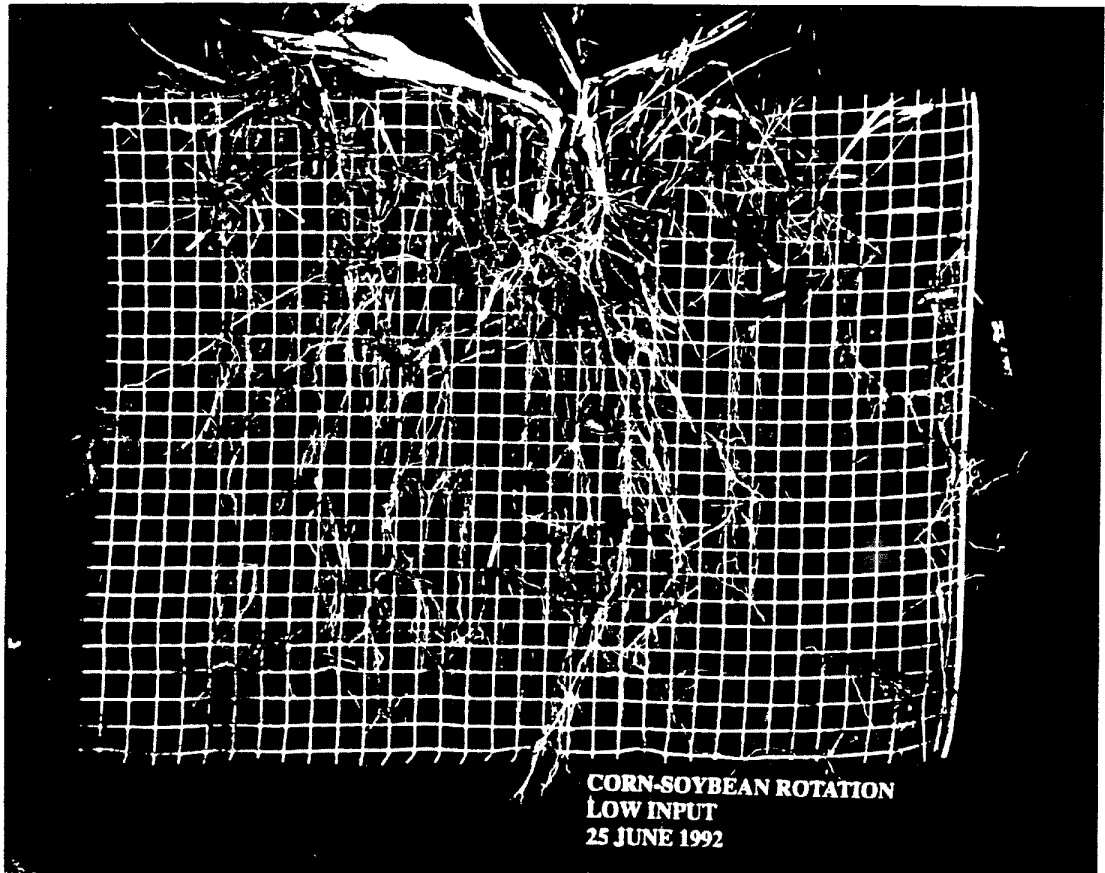


Fig. 3a (Top) Corn crop characteristics from a corn-soybean-small grain/legume rotation with low chemical inputs. Photograph taken July 29, 1992.

Fig. 3b (Bottom) Root system characteristics of a plant sampled from a corn-soybean-small grain/legume rotation with low chemical inputs.

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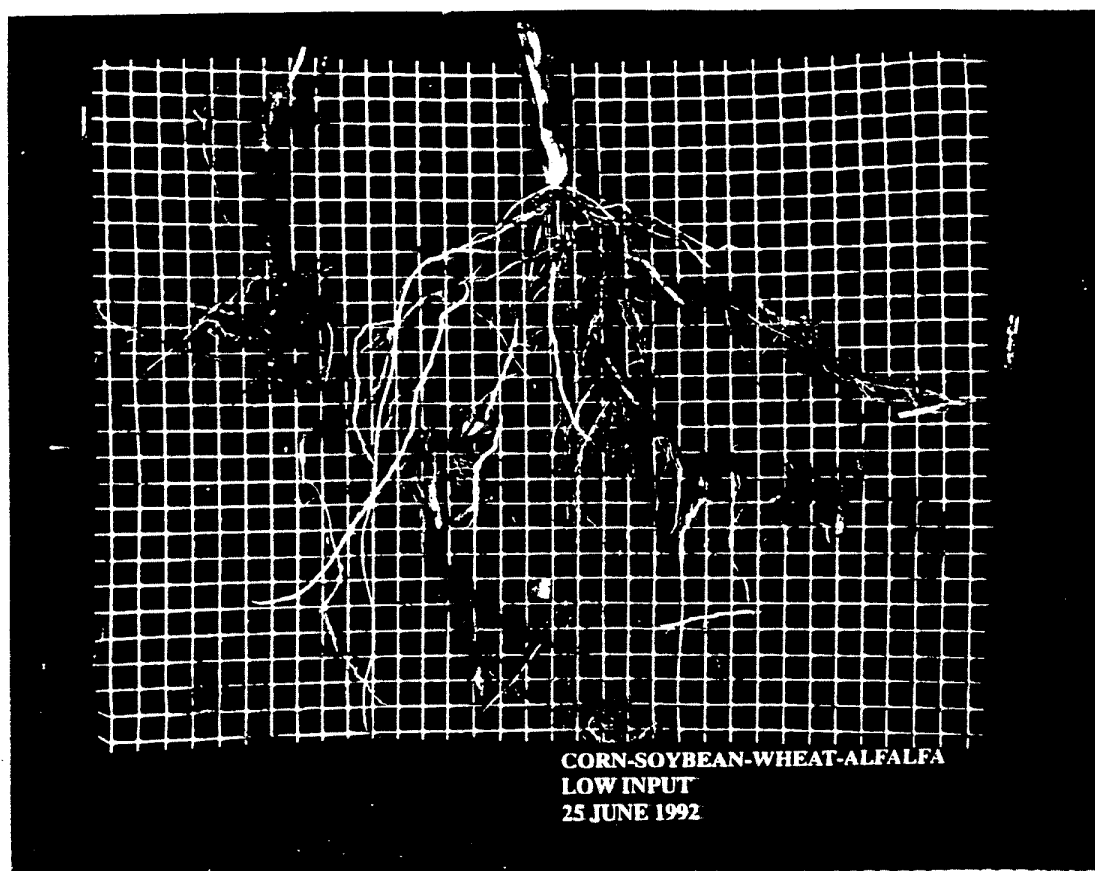
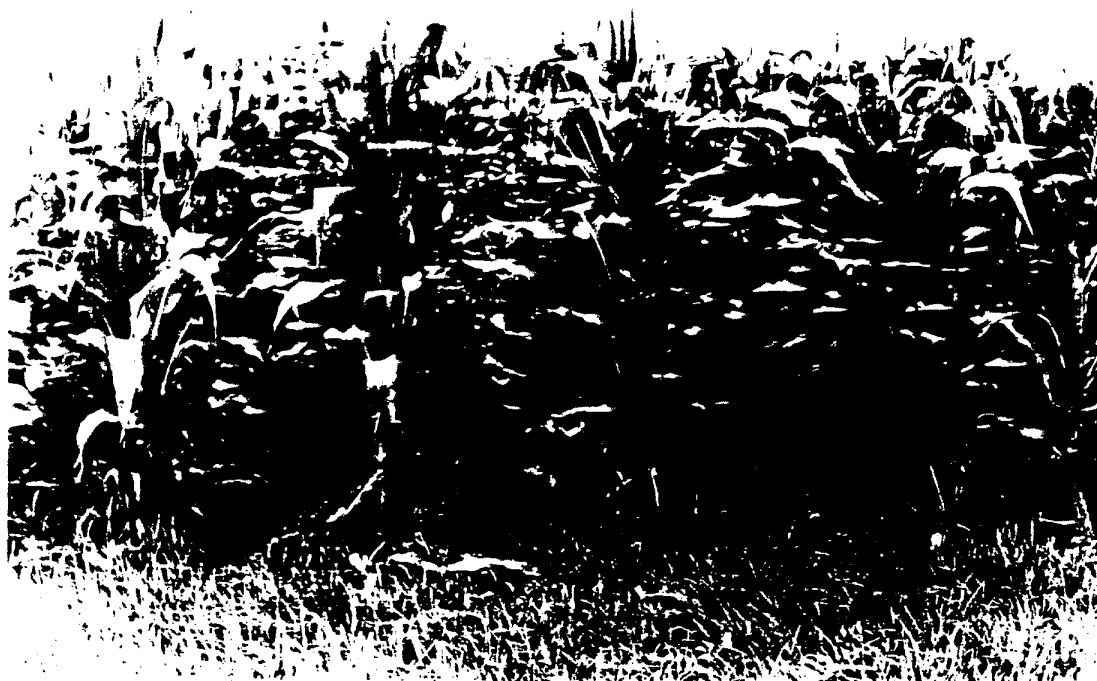


Fig. 4 Plant Dry Weight (g/plant)

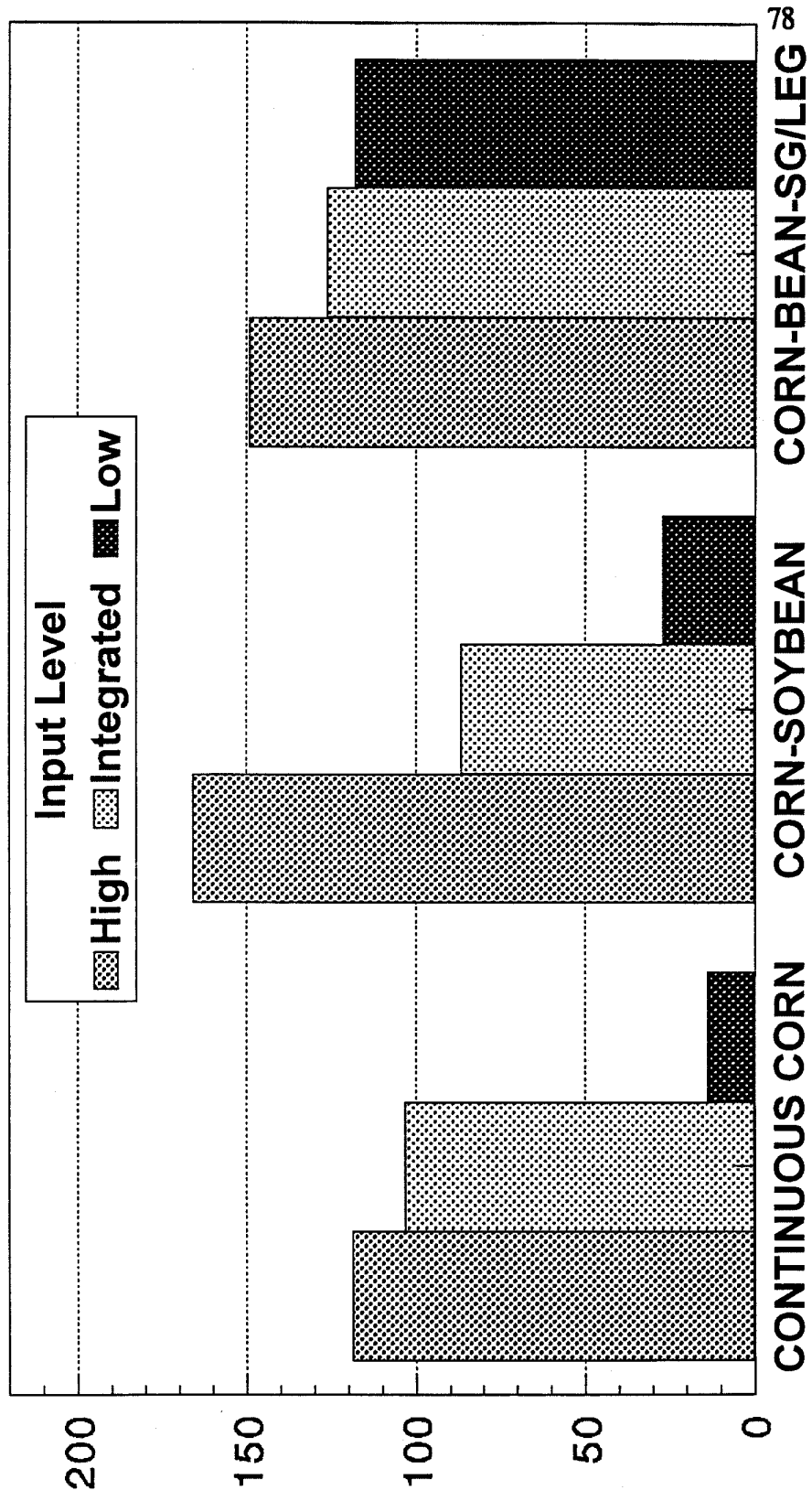
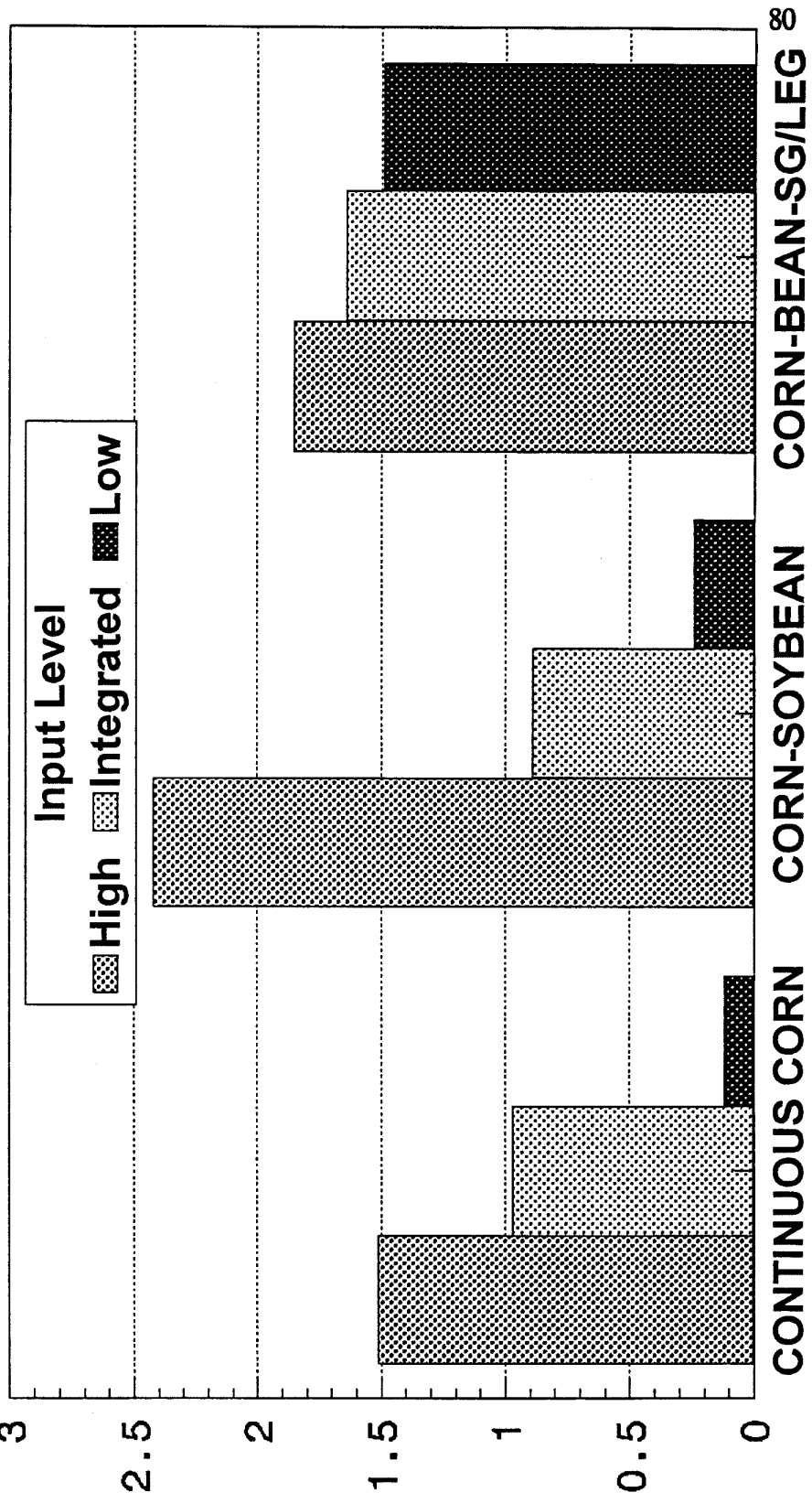


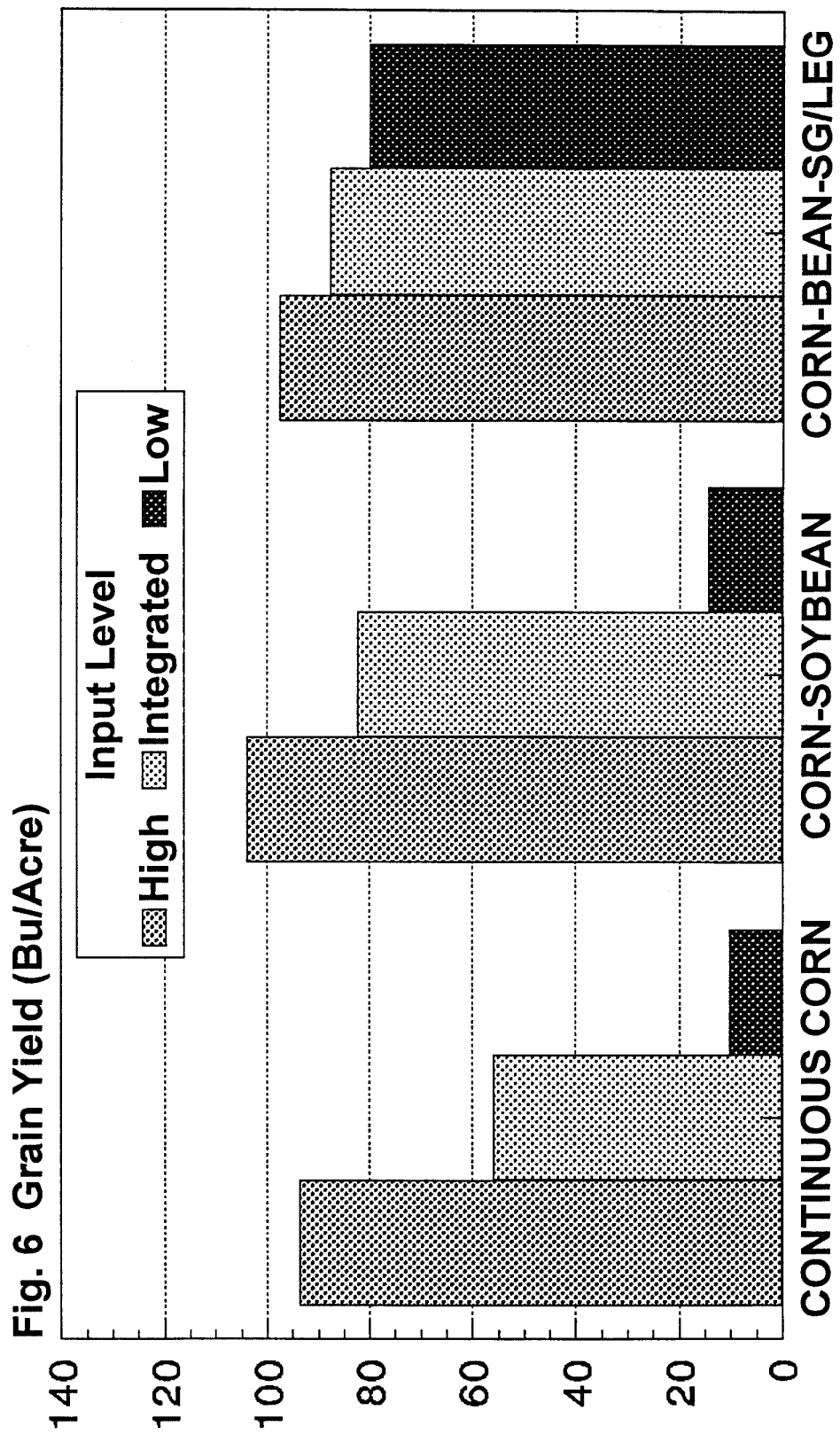
Table 1. Influence of crop rotation and input treatments on corn plant nutrient concentration^a

Rotation	Input	N	P	K	Cu	Fe	Mn	Zn
		%			PPM			
Continuous Corn	H ^b	1.29	0.18	1.48	4.86	46.51	31.05	15.63
	M	0.96	0.18	1.08	3.90	56.92	30.79	20.34
	L	0.24	0.24	1.84	4.87	48.04	29.15	27.60
Corn-Soybean	H	1.45	0.19	1.32	6.15	62.90	31.50	19.00
	M	1.04	0.16	1.09	4.67	52.03	30.88	18.39
	L	0.91	0.19	1.43	4.18	42.66	28.65	26.29
Corn-Bean-Small Grains/Legumes	H	1.24	0.15	1.25	5.56	58.50	30.90	20.63
	M	1.31	0.18	1.52	4.45	45.21	33.03	19.35
	L	1.24	0.15	1.40	5.02	45.41	32.90	23.32

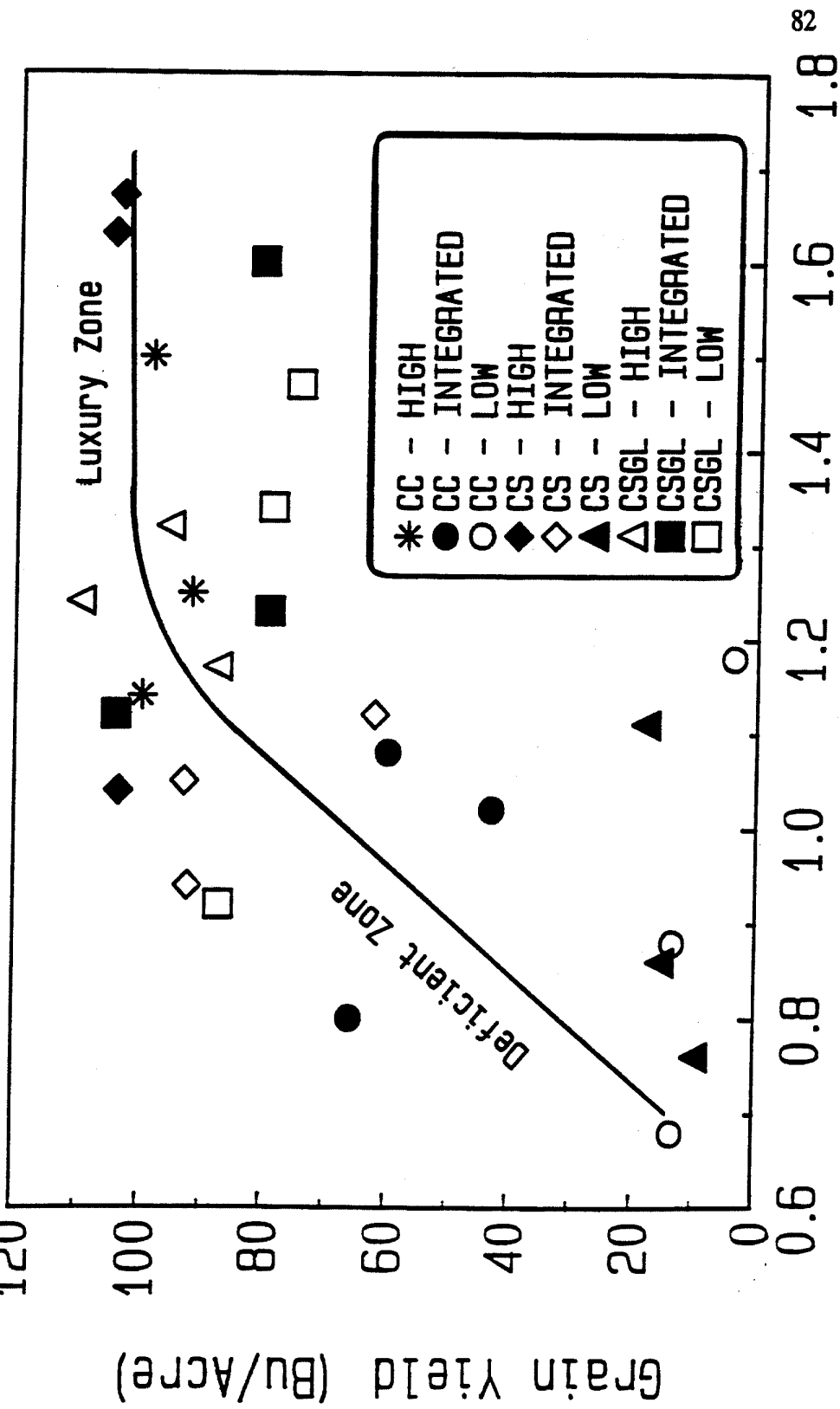
^aPlots were sampled August 5, 1992.^bSymbols denote: H = High, M = Integrated, L = Low

Fig. 5 Total Plant Nitrogen (g/plant)





Nitrogen Use Efficiency and Grain Yield Production



Plant Nitrogen Concentration (%)

Soil Properties of a Cultivated Landscape After Sod

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Problem

Many acres of highly erodible lands (HEL) have been taken out of production by the Conservation Reserve Program (CRP). In 1995, contracts on these lands will begin to expire. The question on how these lands should be handled after CRP has not been adequately addressed. The purpose of this project is to measure how these lands which have been in grass for ten years will respond to cultivation and measure how soil properties related to soil erosion will change in time after returning to crop production. Since these lands are subject to soil erosion, conservation tillage management systems will probably be required and the situation after CRP presents a unique opportunity to introduce no-till management to highly erodible lands.

Approach

Highly erodible land that had been in an alfalfa-bromegrass sod was located near White, SD. This area nearly simulates CRP lands. Seven strips, 40 feet wide, were established across the landscape with four replications. Initial treatments established in the chemically killed sod were moldboard plow, chisel plow, and no-till. These treatments were established in the spring of 1990. In subsequent years, another no-till strip was put into cultivation. A continuous corn rotation was established on all plots. Fertilized and

nonfertilized subplots was also established within each main treatment. Topsoil depths were mapped in a 40x40 foot grid along with depths to carbonates to determine soil erosion phases. Corn yields are measured annually within the 40 foot grid increments.

Accomplishments

Results show that no-till corn production is a feasible management system provided adequate attention is given to fertilizer requirements. Mineralization of soil organic nitrogen was delayed in the no-till system the first year (sod was killed in the spring just prior to planting) and therefore required nitrogen fertilizer to be comparable with the moldboard or chisel plow systems. Yields varied with topsoil thickness. As topsoil thickness decreased (eroded phase) corn yields decreased. This occurred over all tillage systems. The 1992 cropping season was not favorable for corn production. The plots were established in early May, but were severely damaged by frost in late May at the three leaf stage. All plots recovered, but recovery was slowest with no-till. Cool summer temperatures reduced growing degree days and an early September frost killed the crop before physiological maturity. This combination of events resulted in corn grain with a high moisture content and reduced test weight at harvest for all treatments. The no-till treatments established in 1990 and 1992 were the most severely damaged. The no-till established in 1992 was comparable with the chisel and moldboard plow treatments in grain moisture and test weight, but yielded considerably higher.

Interpretation

Results from this study have been variable, but indicate the feasibility of no-till management. Fertilizer will be an important consideration. Casual observation indicate more severe water runoff and sediment transport with the cultivated systems. Crop production on highly erodible lands will continue to be a high risk venture.

Future Plans

The 1993 cropping season will conclude this project. This project presents an ideal situation to investigate soil properties of an eroded landscape which has been in sod management for an extended period and to investigate the changes that will occur in these soil properties as the land is put back into cultivation. This year, plots will have been established which represent long-term sod; first, second, third, and fourth year no-till into sod; and fourth year moldboard and chisel plowing after sod. Extensive soil surface structural properties will be measured to look at pore size distribution, pore geometry, aggregate size distribution, and aggregate stability. Soil structure is critical to supply water, air, and nutrients to the plant roots and is also a contributing factor to soil erodibility. In conjunction with these measurements soil erodibility measurements will also be taken.

Rootworm Emergence Under Different Tillage and Input Schemes

W. David Woodson

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There are a wide variety of management schemes utilized in maize production. Tillage may be conventional or ridge till; crop rotation may be a simple corn soybean rotation, a four crop rotation or none at all; pesticide use can be quite high or nonexistent. The purpose of this study is to examine how some of these different practices affect rootworm populations dynamics and maize yield.

Plot areas were established that had either low, integrated or conventional inputs. Low input plots had neither herbicides nor insecticides applied. Integrated plots had herbicides applied but no insecticides applied. Conventional plots were treated with both herbicides and insecticides. Four rotation schemes were used; continuous corn, corn-soybean, corn-soybean on ridge till and a corn-soybean-wheat-legume rotation.

This year corn rootworms were trapped in the corn-soybean and corn-soybean-wheat-legume rotation plots; none were trapped last year in these plots. The northern corn rootworm has become established in the corn-soybean rotation because of its ability to undergo an extended diapause in the egg stage. These corn-soybean plots will allow long term studies to be undertaken to unravel this insects ability to undermine this rotation scheme. While a small number of corn rootworms were trapped in the corn-soybean-wheat-legume plots the numbers were so low, 5 northern and 7 westerns, that they are insignificant.

The continuous corn plots had large numbers of rootworms emerging for about six weeks (Table 1). This year the western corn rootworm was the dominant species in the plots, last year the northern was the dominant species. This change is most likely due to the large number of eggs that the western lays relative to the northern. The low input plots (no insecticide or herbicide applied) had an average of less than one western and one northern corn rootworms per meter emerging. The integrated plots (no insecticide applied) had an average of two western and one northern corn rootworms per meter emerging. The conventionally managed plots (Dyfonate applied) had an average of one western and one northern corn rootworm per meter emerging. There were approximately four plants per meter of row. These levels are much lower than last year and probably caused by the uncommonly cool wet summer.

Table 1. Mean adult beetle captures in four rotation schemes for summer 1992. CC = Continuous Corn; CS = Corn Soybean; CSr = Corn Soybean in ridge till; CSGl = Corn Soybean Wheat Legume.

INPUTS	HIGH		INTEGRATED		LOW	
ROTATIONS	NCR	WCR	NCR	WCR	NCR	WCR
CC MEAN	0.891	1.000	0.803	1.895	0.071	0.160
CC SEM	0.106	0.142	0.132	0.364	0.021	0.056
CS MEAN	0.513	0.038	0.375	0.013	0.068	0.034
CS SEM	0.070	0.018	0.086	0.013	0.023	0.018
CSGL MEAN	0.013	0.032	0	0	0.019	0.013
CSGL SEM	0.013	0.017	0	0	0.014	0.013
CSr MEAN	0.659	0.037	0.724	0.038	0.173	0.006
CSr SEM	0.115	0.017	0.115	0.015	0.041	0.006